

CLIMATOLOGICAL AND AEROMETRIC ANALYSIS  
ON  
NANTICOKE ENVIRONMENTAL MANAGEMENT PROGRAM  
NETWORK DATA UP TO DECEMBER 1979

REPORT NO: ARB - 18-82-ARSP



MAY 1982

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**NANTICOKE  
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PROGRAM**

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The Nanticoke Environmental Management Program (NEMP) is a joint government - industry venture to monitor air quality in the vicinity of Nanticoke in order to determine the impact of local and distant industrial sources on air quality in the Nanticoke region. The current NEMP network is comprised of 16 gaseous and 16 airborne particulate monitors. In addition to the NEMP network, Ontario Hydro has been operating an SO<sub>2</sub> network of approximately 16 monitors since 1970 and MOE West-Central Region has been operating gaseous monitors at Cheapside and Simcoe as well as a hivol network consisting of 6 samplers. The data set analysed in this report consists of NEMP network data - (October 1978 to December 1979), MOE West-Central Region data - (1979) and Ontario Hydro network data - (1975 to 1979). Monitoring locations for all stations in the Nanticoke area are shown in Figure 1 and a description of the pollutants measured at each station appears in Table 1. Data analysis is focussed on four main areas:

- (1) Description of the climatology of the Nanticoke region showing seasonal and annual wind variations (at 10 and 85 m levels) and seasonal, annual and time-of-day distribution of stability conditions according to Richardson Number.
- (2) An aerometric analysis of the criteria gaseous pollutants annually, seasonally and according to the number of exceedances of the air quality criteria (AQC).
- (3) An analysis of the NEMP precipitation chemistry results.
- (4) An analysis of the airborne particulate matter chemical composition results.

## 2.0 Climatology

Winds in the first kilometre or so from the surface control the dispersal and transport of the pollutants released in this layer (usually termed as the planetary boundary layer PBL). It is therefore important that the behaviour of the winds in this layer be well understood if one is to evaluate the air quality of a given airshed.

### Factors Affecting Winds in the PBL

Although the winds in the PBL are greatly influenced by the large scale synoptic conditions, mesoscale topographical features and large bodies of water such as lakes, modify considerably the wind and temperature field in the PBL. Topographical features can channel winds in a preferred direction, act as barrier to wind flow and produce upslope or downslope winds. Abrupt changes in surface roughness, for example a large forest or smooth terrain, can generate convergent or divergent regions in the air flow.

Large lakes can induce local circulations (commonly known as lake breeze) due to differential heating of land and water. The magnitude of these circulations is primarily dependent on the temperature gradient between land and water and the general synoptic conditions. Weak pressure gradients, clear skies and strong solar insolation favour the development of the lake breeze circulation. Detailed analysis of the lake breeze can be found in the abundant literature on this subject.

In a coastal environment, an internal boundary layer usually develops with an onshore flow in response to the change in two important parameters viz. aerodynamic roughness and thermal properties. This boundary layer typically starts at the shoreline and grows with downwind distance. The rate of growth is governed

largely by the amount of surface heating and wind speed. In a study done by Brookhaven National Laboratories (10) it was observed that the height of the internal boundary layer is inversely proportional to the wind speed and correlated with the temperature difference between land and water. It has been observed in the field (9) and proven theoretically that the profile of the internal boundary layer is approximately parabolic (Figure 2). If the internal boundary layer develops primarily in response to solar heating then it is usually termed as the Thermal Internal Boundary Layer (TIBL).

Formation of the TIBL complicates the diffusion processes in the shoreline. Plumes released upwind from elevated stacks outside the TIBL, will intersect the top surface of the TIBL at some distance downwind. Because of intense mixing in the TIBL, it entrains a large portion of the plume, giving elevated ground level concentration (Figure 2 and (6) for a more detailed description).

Usually the mixed layer heights are obtained from radiosonde soundings of temperature and winds, but since the closest weather station with regular radiosonde flights is Buffalo, an acoustic sounder was deployed about 6 kilometres north-north-east of the generating station. The acoustic sounder determines the temperature structure of the mixed layer by transmitting and receiving the reflected sound signals. The reflected sound signal is recorded on a chart which can be later interpreted to determine the mixing layer height. The sounder has a range of approximately 1500 metres and the accuracy with which the charts can be read is about 50 metres depending upon the legibility of the charts. Even though there is considerable subjectivity in the interpretation of these charts, the acoustic sounder data provides a reasonable picture of the development of the mixed layer.

In the following sections we have attempted to give a general climatological picture of the winds, stability in the lower layer and mixing layer heights in the Nanticoke area. These parameters were chosen because they are the primary controlling factors in the dispersal of pollutants in the mixed layer.

## 2.1 Wind Distribution

The frequent variations, in direction and speed, of the winds over Lake Erie and the surrounding area, are due in part to the many low and high pressure systems which traverse the area. These lows and highs are much more intense and move more rapidly during the winter season. As a consequence, wind speeds are normally higher during the winter season. Ordinarily winds reach higher speeds over open water surfaces than over rougher land surfaces. Consequently winds from the southerly direction are usually higher at Nanticoke due to the long fetch over the open waters of Lake Erie.

The following wind and temperature data analyses are based on the five years of hourly observations from the Jarvis meteorological tower, which is located 12 km inland from the Lake Erie shoreline. Wind direction data were analysed by using the standard 16 point rose. Wind speed was subdivided into five classes according to the World Meteorological Organization classification system. Winds less than or equal to 5 km/hr were defined as calm, and the remaining data were divided into: 6-11 km/hr, 12-19 km/hr, 20-29 km/hr, and 30 + km/hr.

### 2.11 Annual Distribution of Winds

Figures 3 and 4 show the distribution of winds (hourly averaged) at the 10 and 85 m level for the period 1975 to 1979. From the figures it is apparent that the distribution of winds at the 85 m level is quite similar to that of the 10 m level. At both levels, winds are predominantly from the south-south-west to west. Wind speeds in the SSW to W sector are relatively higher than wind speed in other sectors. This is partially due to the presence of the open

lake surface which has a lower roughness than the land. Wind speeds are comparatively higher at the 85 m level than at the 10 m level. Calm winds occur 10.9% of the time at the 10 m level compared to 2.8% of the time at the 85 m level.

#### 2.12 Seasonal\* Distribution of Winds

The fall season at Nanticoke is characterized by a SSW to W air flow with the westerly flow becoming more pronounced at the 85 m level (Figure 5 and 6). At the 85 m level, a large percentage of the winds from the north-east coincides with relatively high wind speeds. This is probably due to the passage of fall storms over Lake Erie. Calm winds represent 11.9 and 2.5 percent of the data from the 10 m and 85 m levels respectively.

During the winter season the predominant wind direction ( 20% of the time) is from the west (Figure 7 and 8). Wind speeds are much higher during the winter period due to the large pressure gradients between strong high and low pressure systems. Calm winds occur less frequently in winter than in summer (5.9% in winter versus 11.9% in summer at the 10 m level).

The frequency distribution of winds during the spring period is much more uniform than it is for the other seasons of the year (Figures 9 and 10). Winds are predominantly from the SSW to NW sector. The frequency of occurrence is similar for all other directions except the NE and ENE direction which together have a 15% frequency of occurrence. Winds are calm 9.7% and 2.8% of the time at the 10 m and 85 m level respectively.

The summer period at Nanticoke is characterized by a predominantly

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\* Winter = Dec-Feb; Spring = March-May; Summer = June-Aug; Fall = Sept-Nov.

SSW to SW wind direction at both the 10 m and 85 m level (Figures 11 and 12). However, wind speeds are lower in the summer, as indicated by the relatively larger percentage of occurrence of wind speed within the 6-11 and 12-19 km/hr classes. The frequency of calm winds is also highest during the summer season. At the 10 m and 85 m levels, calm periods occur 15.8% and 3.6% of the time respectively.

## 2.2 Atmospheric Stability

Atmospheric stability is one of the more important input parameters in determining dispersion rates and hence ground level concentrations of pollutants. Lapse rate (temperature change with height) is often used as a stability indicator; however, it only takes into account buoyancy forces. The Richardson Number (Ri) on the other hand, takes into account both buoyancy and momentum forces making it a better indicator of stability when momentum forces are significant. However, since the Richardson number approach used in this report describes the stability of the atmosphere over the first 85 metres, it would not necessarily be relevant in describing the stability of the Hydro plume which attains a height of approximately 400 metres.

Based on the data available from the Jarvis meteorological tower, a bulk Richardson Number formula as modified by Fulle (1976) was selected. The formula is defined as follows:

$$R_i = \frac{g(\gamma_d - \gamma)}{\gamma_s U^2 / z^2}$$

where  $g = 9.8 \text{ m/sec}^2$

$\gamma_s$  = the surface temperature, ( $^{\circ}\text{K}$ )

$\gamma_d$  = dry adiabatic lapse rate, ( $.98 \text{ }^{\circ}\text{K}/100 \text{ m}$ )

$\gamma$  = atmospheric lapse rate, ( $^{\circ}\text{K}/100 \text{ m}$ )

$u$  = wind speed at 10 m level (m/sec)

$Z$  = height of wind speed measurement (10 m)

No standard categories of this Richardson number were available corresponding to the seven Turner stability classes (4), so categories were developed, based on the resulting distribution of this number for one year of data at Salt Lake City. The categories developed are presented in Table 2. A description of the stability of the atmosphere according to the Richardson number categories is also shown.

Fulle (1976) stated that the classes in Table 2 are site-specific; however, they will be used in this analysis as no other values are available. In future, especially for purposes of mathematical modelling, site specific stability categories should be developed for the Nanticoke area.

The data set consisted of four years of hourly wind speeds and temperatures from the Jarvis meteorological tower. A Richardson number value was calculated for each hour. A frequency distribution of  $R_i$  values was plotted annually, seasonally and according to time of day.

Figure 13a shows the annual frequency distribution of  $R_i$  values based on four years (18,900 hourly data points). Sixty-six percent of the time, the atmospheric stability from the ground to the 85 m level at Nanticoke is neutral. The slightly unstable and slightly stable classes represent 12 and 17 percent of the data respectively. The remaining 5% of the cases are spread among the stable, very stable, unstable and very unstable classes.

Seasonally there is a distinct difference between atmospheric stability as indicated by Figure 14. During the winter season, 98% of the data lies in the neutral to slightly stable stability class. During the summer period the reverse of the winter condition is true in that 28% of the data falls into the unstable class. Unstable conditions enhance the vertical mixing within the lower atmosphere. The greatest variation within atmospheric stability was found during the spring. Fourteen percent of the data represented unstable to very unstable and stable to very stable categories. The fall season had 18% of the data in the stable classes against 8% in the unstable categories. 71% of the fall season is characterized by a neutral atmosphere over the first 85 metres.

The  $R_i$  values were also examined according to daytime (0700 to 1800 hrs) versus nighttime (1900 to 0600 hrs). During the nighttime, conditions are more stable than during the day (Figure 13b). Twenty-eight percent of the nighttime period is characterized by a stable atmosphere while only 7% of the daytime period is represented by stable conditions. The distribution is reversed for unstable conditions. Twenty-three percent of the time conditions are unstable during the day against 2% of the time at night.

Finally an analysis of stability according to  $R_i$  values is shown for three time periods during the day: morning (0700 to 1100 hrs), afternoon (1200 to 1600 hrs) and evening (1700 to 2100 hrs) - Figure 13c. Unstable atmospheric conditions have the greatest frequency of occurrence during the afternoon period and the smallest frequency of occurrence during the evening. Stable conditions occur 4, 14 and 17% of the time during the afternoon, morning and evening periods respectively.

## 2.3 Mixed Layer Heights at Nanticoke

The diurnal and seasonal changes in the characteristics such as height and stability govern the dispersion of pollutants released in or above the mixed layer. In the following sections we briefly examine the frequency distribution and seasonal behavior of the mixed layer heights in the Nanticoke area. In the analysis no distinction was made between the TIBL and PBL. Further stratification of the data is required before we can identify the TIBL data. A total of 3000 hours of data were extracted from the acoustic sounder charts and analysed for the period Feb. 1979 to Oct. 1980.

### 2.3.1 Distribution of Mixed Layer Heights

Figure 16 shows the behaviour of average daily mixed layer heights for winter, spring, summer, and fall. The most notable feature of Figure 16 is the different growth rate of the mixed layer, which grows rapidly with the sunrise reaching its maximum value before noon during summer and fall, whereas during winter and spring the growth is much slower and the maximum height is attained after 12 noon. Another significant difference is the presence of a pronounced secondary peak in summer and a smaller peak in fall. This secondary peak is absent in the winter and spring season and for northerly flow (see Figure 16). This secondary peak may indicate the passage of the lake breeze fronts. With the onset of a lake breeze, cold lake air is advected overland and erodes the mixed layer. After the front passes through, the mixed layer builds up again which shows up as the secondary peak in Figure 16.

If we compare the average maximum heights for all the seasons, it is apparent that there is not a big difference. This is because of the lake effect. During winter, warm unstable air from the lake when advected overland will erode the stable surface layer thus giving higher mixed layer heights. During summer the process is reversed, cold stable air is advected overland (due to lake breeze or

general synoptic conditions) which will inhibit the growth of the mixed layer near the shoreline.

### 2.3.2 Frequency Distribution of Mixed Layer Heights

Annual and seasonal contingency tables for the mixed layer heights at Nanticoke are shown in Tables 3 and 4. Seasonally mixed layer heights are higher than 400 m (400 meter was selected as reference height because the average plume height of Nanticoke Generating Station (NANTGS) is around 400 meters). During spring and summer TIBL heights greater than 400m occur more frequently with winds from the SE to SW quadrant, whereas in winter, winds from the northerly direction correlate with high mixed layer heights. In fall except for westerly winds (high TIBL heights) and easterly winds (low TIBL heights) the distribution is fairly uniform.

### 3.0 Aerometric Analysis of Gaseous Compounds

The hourly average gaseous concentrations as a function of wind direction for four gaseous compounds - namely sulfur dioxide ( $\text{SO}_2$ ), ozone ( $\text{O}_3$ ), total reduced sulfur (TRS), and nitrogen dioxide ( $\text{NO}_2$ ) have been plotted annually, seasonally, and according to the number of exceedances of MOE's air quality criteria, for each station in the Nanticoke area (Figures 17 to 28). Also included on the plots are wind frequencies at the Jarvis meteorological tower.

#### 3.1 Distribution of $\text{SO}_2$

The  $\text{SO}_2$  analysis is based on hourly averaged concentrations obtained from Ontario Hydro's network (1975 to 1979), MOE's West Central Region (1976 to 1979) and the NEMP network (1979). Monitoring stations were located according to criteria that take into account predominant wind patterns, source configuration; as well as to be able to differentiate between industrial and other types of contributions. It should be noted that a fixed monitoring network does not always record the maximum ground level concentration (glc). Although the Nanticoke area has a good coverage by monitors, plume impingement between monitors as well as beyond the range of the network is possible. Further complicating the situation is the complex dispersion due to the meteorology within a shoreline environment. However, accumulation of data over a sufficiently long period of time should allow aerometric analyses such as the present one to draw valid conclusions about the contributions of local and other emission sources to air quality in the area.

### 3.1.1 Annual SO<sub>2</sub> Distribution

The annual concentration rose for SO<sub>2</sub> data collected for each site during the 1975 to 1979 period is shown in Figure 17. Most of the monitors which are located in the NNE to NE quadrant show correlation between high SO<sub>2</sub> levels and winds from the SSW to SW direction; monitors located in the NNW to N quadrant show correlation between relatively high SO<sub>2</sub> concentrations and SSE to S wind flow probably indicating the effect of the NANTGS on air quality within the surrounding area. Correlation between high SO<sub>2</sub> concentrations and winds from the S to SSW direction at E05, W13 and WNWO3, suggest that sources south of the lake also contribute to high SO<sub>2</sub> in the Nanticoke area.

### 3.1.2 Seasonal SO<sub>2</sub> Distribution

Highest averaged SO<sub>2</sub> concentrations occur during the winter period - Figure 18. High NANTGS loads due to peak demand, a high frequency of occurrence of stable atmospheric conditions and high wind speeds coincide with the elevated SO<sub>2</sub> concentrations during the winter season. Also, these high SO<sub>2</sub> concentrations show a consistent correlation with winds from the south indicating that the sources to the south including the Hydro plant influence SO<sub>2</sub> levels in the Nanticoke area. Previous studies on the long range transport of SO<sub>2</sub> and present data as indicated in Figure 18 show that SO<sub>2</sub> advected across Lake Erie during the winter period is significant (3) (12). Local sources (space heating) also contribute to high concentrations during the winter.

During the summer, spring and fall seasons, the average SO<sub>2</sub>

concentrations are comparatively lower than during the winter period. However, the correlation of high concentrations with winds from the SE to SW sector, suggests that sources from the south including the Hydro plant have an influence on  $\text{SO}_2$  levels in the Nanticoke area.

### 3.1.3 $\text{SO}_2$ Exceedances of the AQC

During the five year period of interest there were 74 exceedances of the hourly (250 ppb) AQC, 1 exceedance of the daily (100 ppb) AQC and no exceedances of the annual (20 ppb) AQC. Of the 74 hourly exceedances, all but two can be associated with winds from the south which includes transport across the lake and from the generating station towards the monitors (Figure 22). The remaining two hourly exceedances at WNW20 and NNE16 occurred during light and variable winds. Prior to and during the recording of the high glc at WNW 20 the wind shifted from SSE to E. Plume fumigation was responsible for this exceedance. The exceedance at NNE 16, occurred at 1800 hours. Elevated glc's were most likely the result of a frontal passage. Seventy-three per cent of the hourly exceedances occurred during the spring and summer period. In spring and summer, the differential heating of the land and water causes the formation of the TIBL. As the plume impinges on the boundary layer, the plume material is convectively mixed to the ground thereby producing elevated glc's of  $\text{SO}_2$ .

The one daily exceedance of the AQC occurred on January 24, 1977. The daily average concentration was 106 ppb at N15. Steady winds from the SW and high  $\text{SO}_2$  concentrations recorded by all monitors between 0100 and 0400 hours suggests sources south of Lake Erie were responsible for this episode. A comprehensive study of each of the  $\text{SO}_2$  exceedance episodes will be carried out in a future report.

### 3.2 Ozone ( $O_3$ ) Distribution

Within the Nanticoke region, ozone is monitored at three stations SW37, NNE39 and WNW19. In the presence of sunlight, a series of photochemical reactions may take place between nitrogen oxides and hydrocarbons producing ozone. Conditions conducive to ozone formation are most probable during late spring or summer. Ozone data collected during 1979 is analysed in this section.

#### 3.2.1 Annual Ozone Distribution

The annual (hourly averaged)  $O_3$  concentrations as a function of wind direction for each station are presented in Figure 23. Average concentrations are in the 35 to 45 ppb range for SE to SSW air flow compared to a range of 15 to 25 ppb for northerly flow. The annual (hourly averaged)  $O_3$  concentration for 1979 was highest at the coastal location (SW37) and decreased as one moved inland. In the summer of 1981 an attempt was made to establish if a consistent gradient in the ozone levels exists with distance inland. Due to poor meteorological conditions, no conclusive results were obtained (7).

#### 3.2.2 Seasonal Ozone Distribution

Ozone concentrations are lowest during the winter season and highest during the summer period (Figure 23). High summer  $O_3$  concentrations generally coincide with strong solar insolation and southerly flows. Average concentrations from the southerly quadrants again exceed those from the northerly sector. For station SW37, highest hourly averaged  $O_3$  concentrations occur with winds from the south suggesting regional or long range transport.

#### 3.2.3 Ozone Exceedances of the AQC

The Ontario AQC for  $O_3$  is a one-hour average of 80 ppb. During 1979, the AQC was exceeded 216 times. SW37 had 86 exceedances, WNW20 had 96 and NNE39 reported only 34. Sixty-eight percent of the AQC exceedances

occurred during a WSW to S air flow (Figure 23). The monthly frequency distribution of  $O_3$  exceedances is shown in Table 5. Eighty-nine percent of the exceedances occurred during the summer season, whereas only 4% and 7% of the hourly  $O_3$  exceedances occurred during the spring and fall seasons respectively.

### 3.3 Distribution of Total Reduced Sulfur (TRS)

In 1979 the NEMP network recorded TRS concentrations at three stations: NNE05, NNW08 and NNE 10. Two of these stations were located downwind of the major industrial sources of TRS (Texaco and Stelco) and the third station was placed to provide background values. Seepages from natural gas wells also might contribute to the TRS levels in the Nanticoke area (Figure 24). Stelco did not operate during 1979. Texaco refinery operated throughout most of 1979. However, the sulfur recovery unit (SRU) was not commissioned until June 12, 1979. TRS levels will be considered during the pre/post - commissioning situation. TRS concentrations as a function of wind direction are presented in Figures 25 to 27.

#### 3.3.1 Annual TRS Distribution

The annual (hourly averaged) TRS concentrations for 1979 were well below 1 ppb for all stations in the NEMP network. Annual TRS concentrations for each site during 1979 are shown in Figure 25. Relatively high TRS concentrations were recorded in the WSW to SW wind sector for station NNE10, in the WSW sector for NNE05 and in the NNE and ENE sector for NNW08.

The sulfur recovery unit at the Texaco refinery was commissioned June 12, 1979. Concentration roses were constructed for this pre/post commissioning period (Figure 25). Results revealed that ambient TRS levels in the Nanticoke area decreased after the commissioning of the SRU.

### 3.3.2 Seasonal TRS Distribution

Seasonal TRS concentration roses are shown in Figure 26. TRS concentrations are lowest during the summer and fall season and highest during the winter and spring. Additional data is required in order to assess the seasonal distribution of TRS in the Nanticoke area.

### 3.3.3 TRS Exceedance of the $H_2S$ Criterion

At present there is no AQC for TRS. However, preliminary results of inplant monitoring during the fall of 1981 at Texaco and Stelco suggests that TRS emissions include a large proportion of hydrogen sulfide ( $H_2S$ ). The MOE (one hour average) AQC for  $H_2S$  is 20 ppb. This guideline was used in the analysis of the Nanticoke TRS data. Further investigation into a suitable criteria for TRS/ $H_2S$  levels is being continued. Additional in plant monitoring has been recommended for some time in 1982.

During 1979 two elevated values occurred at NNE05, (Figure 27). A maximum (hourly averaged) concentration of 60 ppb occurred during a WSW flow and a second exceedance of 43 ppb occurred with a SW wind. Both exceedances were recorded prior to the commissioning of the SRU.

### 3.4 Distribution of Nitrogen Dioxide ( $NO_2$ )

$NO_x$  emissions are mainly due to high-temperature combustion processes (internal combustion engines, fossil fuel-fired generating stations, etc.). Oxides of nitrogen ( $NO_x$ ) are considered to be the sum of nitric oxide (NO) and nitrogen dioxide ( $NO_2$ ). Nitric oxide (NO) is measured directly and the total oxides ( $NO_x$ ) are measured by internally converting all other nitrogen oxides to nitric oxide. Nitrogen dioxide is derived as the difference of the two measurements. NO and  $NO_x$  are monitored at SW37, NNE39, and NO7. The hourly AQC for  $NO_2$  is 200 ppb. During 1979 there were no exceedances of the AQC at any of the monitoring locations. Table 6 shows the percentage of valid data annually and seasonally for each NEMP station reporting NO/ $NO_x$ .

concentrations. Any station reporting less than 75% valid data was not included in the analysis.  $\text{NO}_2$  concentrations as a function of wind direction are shown in Figure 28.

#### 3.4.1 Annual $\text{NO}_2$ Distribution

NNE39 was the only NEMP station which reported in excess of 75% valid data for the full year during 1979. The annual average  $\text{NO}_2$  concentration at NNE39 was less than 13 ppb. The highest (hourly averaged)  $\text{NO}_2$  concentrations (20 ppb) were recorded at NNE39 when winds were in the N to SE quadrant (Figure 28). High  $\text{NO}_2$  concentrations at NNE39 may be influenced by the industrial areas of Hamilton, St. Catherines, Niagara Falls and Buffalo.

#### 3.4.2 Seasonal $\text{NO}_2$ Distribution

$\text{NO}_2$  concentrations are highest during the winter season for NNE39. Hourly  $\text{NO}_2$  averages during the winter are higher during the nighttime compared to the daytime period. Highest  $\text{NO}_2$  concentrations during the spring at SW37 occurred during NE winds and at NO7 during S and NNE winds. The absence of continuous  $\text{NO}/\text{NO}_x$  data during 1979 has made analysis difficult. The addition of the 1980 data should aid in a better analysis of  $\text{NO}_2$  concentration levels.

#### 4.0 Analysis of Precipitation Data

There are two basic mechanisms responsible for the removal of the material emitted into the atmosphere: viz wet and dry deposition. At present there is considerable concern about the effects of the deposition of acid and other substances by precipitation, especially in aquatic ecosystems. Calcareous soil at Nanticoke acts as a buffering agent and therefore acid rain is not of the same concern at Nanticoke as it is in other areas, e.g. Haliburton and Muskoka. Nevertheless, the Nanticoke area is being monitored to determine the relative effects of local and distant sources on precipitation chemistry.

In October 1978, the NEMP precipitation network was established to (1) determine the precipitation quality in the Nanticoke area with special regard to acidic substances and (2) to monitor the trends in precipitation quality over the years. The NEMP network collects monthly samples of rain or snow at seven sites throughout the Nanticoke region (Figure 29). These samples are analysed for pH, major ions and trace metals. The chemical analysis for all precipitation samples collected during October 1978 to December 1979 for the entire NEMP network is listed in Appendix 1.

The present section contains a brief discussion of the main features of the precipitation chemistry data. Seasonal trends will be discussed in a future report, as it is difficult to comment on trends with only one year's data. In Appendix 2 an intercomparison is carried out between the results of the NEMP precipitation sampling network for  $H^+$ ,  $NO_3^-$ ,  $NH_4^+$  and  $Ca^+$  with other samplers operated independently in the Nanticoke area by the Atmospheric Environment Service (CANSAP) and Ontario Hydro. It is shown that generally there is no statistical difference at the 95% confidence level between the different sets of results, thus establishing confidence in our data.

Figure 30 shows the monthly variation of pH,  $\text{SO}_4^{=}$ ,  $\text{Ca}^+$  and  $\text{NO}_3^-$  for the entire NEMP network. Monthly weighted means as well as minimum and maximum concentrations are shown on the graphs.

The average pH for wet deposition in the NEMP network during 1979 is 4.1 (Figure 30). This value is very similar to that shown by the pH Isopleth Map, (Figure 31) in which the precipitation weighted pH for 1979 based on the National Atmospheric Deposition Program (NADP) and Canadian (CANSAP) networks for the Nanticoke area was found to be about 4.1. (13)

Volume weighted mean sulphate (in precipitation sample) concentration for the NEMP network is 5.7 mg/l whereas the 1979 NADP and CANSAP sulphate data (Figure 32), show an  $\text{SO}_4^{=}$  average value of 2 to 3 mg/l. Thus it appears that  $\text{SO}_4^{=}$  concentrations in the Nanticoke area are higher than would be expected from other measurements in Southwestern Ontario and nearby areas in the United States, possibly due to local industrial activity.

The network volume weighted mean for precipitation nitrate and calcium are 3.6 and 0.71 mg/l respectively.

Trace metal concentrations in the precipitation samples for the NEMP network are listed in Table 7. Arithmetic means, standard deviations, minimum and maximum values are calculated for Ca, Cd, Cu, Fe, K, Mg, Na, Ni, Pb, Zn and Mn and expressed as network averages.

## 5.0 Analysis of Airborne Particulates Data

The particulate monitoring network in the Nanticoke area consists of 13 hi-vol samplers operated by NEMP (Figure 33). The analysis to follow was carried out on the 13 samplers. Glass fibre filters are used at all stations with parallel sampling on Whatman 41 cellulose filters at 8 stations. TSP measurements are carried out on the glass fibre filters while a detailed chemical analysis is done on selected Whatman 41 filters. Some of the glass fibre filters are also analysed for polynuclear aromatic hydrocarbons and inorganic and total carbon. Data is collected every sixth day with a 24 hour sampling period. At three sampler locations samples are collected every three days. Data analysis has shown that there is no significant difference between the third day and sixth day sampling means (11), therefore, the results from the six-day sampling cycle are used in the following analysis.

Annual sulphate, nitrate, calcium, magnesium and TSP levels, as a function of wind direction for the period January to December 1979 are presented in Table 8. Wind directions were extracted from the monthly meteorological summaries at Simcoe, Ontario. They represent the most frequent hourly direction during a 24 hour period. Annual concentrations of  $\text{SO}_4^{=}$ ,  $\text{NO}_3^{-}$ ,  $\text{Ca}^{+}$ , Mg and TSP are generally higher during southerly versus northerly air flows.

TSP geometric mean for the NEMP network during 1979 was  $45.0 \text{ ug/m}^3$ . There were in total 19 exceedances of the daily TSP criteria of  $120 \text{ ug/m}^3$ . The highest number of exceedances (9) occurred at SW37. These high values were probably due to windblown dust. Network geometric means for  $\text{SO}_4^{=}$ ,  $\text{NO}_3^{-}$ ,  $\text{Ca}^{+}$  and Mg are 5.3, 3.0, 0.90 and  $0.28 \text{ ug/m}^3$  respectively. Table 9 lists the estimated AQC for several airborne particulates, for comparison with the NEMP results. Estimates are based on Regulation 15 of the Environmental Protection Act, 1971.

The Whatman 41 filters are submitted to the laboratory for a chemical analysis that includes a number of other elements - Al, Cd, Fe, Mn, Ni, Pb, Zn, B, Cr, Si and Ti. Results for the NEMP network are shown in Table 10.

The polynuclear aromatic hydrocarbon (PAH) results, according to wind direction patterns for the NEMP network, are shown in Table 8. Results are similar to other rural areas and considerably less than those found in the vicinity of certain sources and industries in other areas of Ontario (14). Total carbon (TC) and free carbon (FC) results associated with different wind directions are also found in Table 8.

## 6.0 Conclusions

In this report, it has been attempted to establish a relationship between the NEMP, MOE, and Ontario Hydro network data and the 10 and 85 m winds from the Jarvis meteorological tower. Seasonal and annual average wind directions have been determined for the Nanticoke area. A strong westerly wind component is observed during the winter season and a strong southerly component during the summer. High wind speeds during the spring, summer and fall season are associated with southerly wind flow. Wind speeds during the winter period are consistently higher than during other seasons of the year. High wind speed during this season is coincident with elevated  $\text{SO}_2$  readings.

An analysis of atmospheric stability based on the Richardson number showed the atmosphere to be more stable during the winter season. During the morning period (0700 to 1100 hrs) the atmosphere was found to be relatively stable while during the afternoon period (1200 to 1600 hrs) it is relatively unstable.

Elevated  $\text{SO}_2$  concentrations correlate well with southerly wind flow patterns suggesting that the NANTGS and sources south of the lake influence the high concentrations. Sources south of the lake increase the background  $\text{SO}_2$  level, especially in winter however, elevated one-hour concentrations are probably all due to local industry. A detailed study of the exceedance episodes is necessary in order to delineate more specifically the cause of these high concentrations.

Ozone levels during 1979 are highest in the late spring and summer. Elevated  $\text{O}_3$  concentrations at SW37 during southerly wind flow patterns suggests the source of the pollutant to be south of the border.

Annual average TRS concentrations are below 1 ppb.

The directional distribution of the  $\text{NO}_2$  values coincide with the close proximity of the industrial centres of Hamilton, St. Catharines, Niagara Falls and Buffalo.

Precipitation data from the NEMP network for the period October 1978 to December 1979 have been validated by intercomparing with other networks in the Nanticoke area. Average pH for the 1979 NEMP precipitation data was 4.1.

Airborne particulate analysis of 1979 NEMP data showed higher concentrations of  $\text{SO}_4^{=}$ ,  $\text{NO}_3^-$ ,  $\text{Ca}^+$  and Mg during southerly air flow. High TSP levels during the summer period are attributed primarily to wind blown dust. The polynuclear aromatic hydrocarbon concentrations were relatively low, quite typical of rural areas.

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PK/as: AR 9-15

NE 11-04-02

TABLE 1 Station Location and Description

OGRAPIICAL ID	AQUIS ID	E-W UTM#	N-S UTM#	SITE NAME	INSTRUMENT, COMPLIMENT AND NOTES	MAINTAINED
SW37	22901	05102	47138	Long Point Park	SO <sub>2</sub> (Phillips) O <sub>3</sub> (Bendix) NO <sub>x</sub> (Teco) CO <sub>x</sub> (Bendix) TSP Hi-Vol (Gen. Met.) Comp. Hi-Vol (Gen. Met.) Auto APM (GCA) COH (RAC)	NEMP Contract
SW40	22959	05454	47152	Big Creek	Precip Gauge (F/P) Precip Collector (Sangamo)	NEMP Contract
W07	22953	05702	47396	Dogs Nest East	TSP Hi-Vol (Gen. Met.) Comp. Hi-Vol (Gen. Met.) Precip Collector (Sangamo) Precip Gauge (F/P)	NEMP Contract
W13	22861	05641	47383	Port Dover	SO <sub>2</sub> (Phillips) Data Recorder (West)	Hydro CTS/NGS
	22056				TSP Hi-Vol (Gen. Met.)	MOE/WCR
WNW03	22871	05752	47398	Nanticoke Village	SO <sub>2</sub> (Phillips) Data Recorder (West)	Hydro CTS/NGS
WNW19	22071	05597	47449	Simcoe Horticultural	SO <sub>2</sub> (Teco) O <sub>3</sub> (Bendix) NO <sub>x</sub> (Teco) COH (RAC)	MOE/WCR
WNW20	22872	05596	47485	Bloomsburg	SO <sub>2</sub> (Phillips) Data Recorder (West)	Hydro CTS/NGS
WNW3	22961	05758	47412	Nanticoke North	TSP Hi-Vol (Gen. Met.) Comp. Hi-Vol (Gen. Met.)	NEMP Contract
WNW08	22881	05744	47456	Nanticoke Road	SO <sub>2</sub> (Phillips) Data Recorder (West)	Hydro CTS/NGS
	22905				TRS (Phillips) HC (Byron) 2 Data Recorders (West)	NEMP Contract
WNW11	22882	05712	47478	Jarvis	SO <sub>2</sub> (Phillips) Data Recorder (West)	Hydro CTS/NGS
	22032				TSP Hi-Vol (Gen. Met.)	MOE/WCR
WNW12	22883	05744	47499	Jarvis Met. Tower	10 m wind speed/dir (Bendix) 10 m temperature (Rosemont) 10 m dewpoint (Honeywell) 30 m wind speed/dir (Bendix) 85 m wind speed/dir (Bendix) 85 m temperature (Rosemont) 12 Data Recorders (West)	Hydro CTS/NGS
WNW15	22884	05717	47522	Livingston	SO <sub>2</sub> (Phillips) Data Recorder (West)	Hydro CTS/NGS
WNW16	22954	05654	47535	Ville Nova	TSP Hi-Vol (Gen. Met.) precip. Collector (Sangamo)	NEMP Contract

TABLE 1 Cont

GEOGRAPHICAL ID	AQUIS ID	E-W UTM#	N-S UTM#	SITE NAME	INSTRUMENT, COMPLIMENT AND NOTES	MAINTAINED
H07	22811	05787	47458	Sandusk	SO <sub>2</sub> (Philips) Data Recorder (West)	Hydro CTS/HGS
	22906				NO <sub>x</sub> (Teco) Data Recorder (West)	NEMP Contract
	22069				TSP Hi-Vol (Gen. Met.)	MOE/WCR
H15	22812	05774	47535	Garnet	SO <sub>2</sub> (Philips) Data Recorder (West)	Hydro CTS/HGS
H17	22951	05768	47548	Hagersville South	TSP Hi-Vol (Gen. Met.) Comp. Hi-Vol (Gen. Met.)	NEMP Contract
HNE05	22921	05794	47434	Walpool South School	SO <sub>2</sub> (Philips) Data Recorder (West)	Hydro CTS/HGS
	22904				TRS (Philips) HC (Byron) 2 Data Recorders (West) TSP Hi-Vol (Gen. Met.) Comp. Hi-Vol (Gen. Met.)	NEMP Contract
HNE09	22822	05838	47463	Dry Creek	SO <sub>2</sub> (Philips) Data Recorder (West)	Hydro CTS/HGS
HNE10	22086	05821	47472	Cheapside	SO <sub>2</sub> (Teco) NO <sub>x</sub> (Teco) COil (RAC) TSP Hi-Vol	MOE/WCR
HNE10	22903	05821	47472	Cheapside	TRS (Philips) HC (Byron) Auto APM (GCA)	NEMP Contract
HNE16	22823	05872	47518	Balmoral	SO <sub>2</sub> (Philips) Data Recorder (West)	Hydro CTS/HGS
HNE20	22825	05880	47561	Decewsville	SO <sub>2</sub> (Philips) Data Recorder (West)	Hydro CTS/HGS
HNE22	22960	05839	47600	Oufferin North	TSP Hi-Vol Precip Collector (Sanyamo)	NEMP Contract
HNE39	22902	05914	47746	Binbrook West	SO <sub>2</sub> (Philips) O <sub>3</sub> (Bendix) NO <sub>x</sub> (Teco) CO (Bendix) TSP Hi-Vol (Gen. Met.) COil (RAC) Precip Collector (Sanyamo) Precip Gauge (F/P)	NEMP Contract
H207	22962	05818	47443	Dry Creek West	Acoustic Sounder	NEMP Contract

TABLE 1 Cont

GEOGRAPHICAL ID	AQUIS ID	E-W UTM	N-S UTM	SITE NAME	INSTRUMENT, COMPLIMENT AND NOTES	MAINTAINED BY
NE16	22957	05866	47509	Fisherville North	TSP Hi-Vol (Gen. Met.) Comp. Hi-Vol (Gen. Met.)	NEMP Contract
NE19	22832	05935	47489	Kohier Road	SO <sub>2</sub> (Philips) Data Recorder (West)	Hydro CTS/NGS
NE27	22956	06026	47527	Canfield South	TSP Hi-Vol (Gen. Met.) Precin Collector (Sangamo) Precin Gauge (F/P)	NEMP Contract
NE41	22958	06109	47607	Canboro East	TSP Hi-Vol (Gen. Met.) Precin Collector (Sangamo)	NEMP Contract
ENE11	22841	05870	47434	Selkirk	SO <sub>2</sub> (Philips) Data Recorder (West)	Hydro CTS/NGS
	22031				TSP Hi-Vol (Gen. Met.)	MOE/MCR
ENE17	22955	05943	47441	Rainham Centre South	TSP Hi-Vol (Gen. Met.) Comp Hi-Vol (Gen. Met.)	NEMP Contract
ENE18	22842	05950	47445	Rainham Centre	SO <sub>2</sub> (Philips) Data Recorder (West)	Hydro CTS/NGS
E04	22952	05822	47388	Peacock Point Park	TSP Hi-Vol (Gen. Met.) Comp Hi-Vol (Gen. Met.)	NEMP Contract
E05	22851	05831	47380	Peacock Point	SO <sub>2</sub> (Philips) Data Recorder (West)	Hydro CTS/NGS

TABLE 2

RICHARDSON NUMBER CATEGORIES - FULLE(1976)

TURNER STABILITY CLASS	RICHARDSON NUMBER	STABILITY CHARACTERISTICS
1	$Ri < -1.0$	VERY UNSTABLE
2	$-1.0 \leq Ri < -0.2$	UNSTABLE
3	$-0.2 \leq Ri < 0.0$	SLIGHTLY UNSTABLE
4	$0.0 \leq Ri < 0.2$	NEUTRAL
5	$0.2 \leq Ri < 0.8$	SLIGHTLY STABLE
6	$0.8 \leq Ri < 2.0$	STABLE
7	$Ri \geq 2.0$	VERY STABLE

TABLE 3

SEASONAL DISTRIBUTION OF BLH (M) ACCORDING  
TO WIND DIRECTION

## WINTER

SECTOR	N	NE	E	SE	S	SW	W	NW
AVERAGE HT	205	230	128	261	281	206	245	220
MAXIMUM HT	600	540	300	660	450	450	900	750
OCCURRENCES	77	125	44	20	21	56	73	68

## SPRING

SECTOR	N	NE	E	SE	S	SW	W	NW
AVERAGE HT	125	199	174	208	180	257	275	152
MAXIMUM HT	600	960	540	750	720	1250	900	750
OCCURRENCES	70	206	101	77	146	209	89	70

## SUMMER

SECTOR	N	NE	E	SE	S	SW	W	NW
AVERAGE HT	148	177	166	266	245	209	194	194
MAXIMUM HT	900	1050	570	600	750	900	900	1050
OCCURRENCES	53	151	66	53	205	273	136	134

## FALL

SECTOR	N	NE	E	SE	S	SW	W	NW
AVERAGE HT	209	220	152	222	233	226	255	232
MAXIMUM HT	1050	1050	1050	680	1260	750	900	1200
OCCURRENCES	110	221	115	56	222	234	329	186

BLH are obtained from Acoustic Sounder charts

TABLE 4

SEASONAL DISTRIBUTION OF BLH > 400 ft  
ACCORDING TO WIND DIRECTION

## WINTER

SECTOR	N	NE	E	SE	S	SW	W	NW
AVERAGE HT	477	455	0	640	450	450	900	750
MAXIMUM HT	600	540	0	660	450	450	900	750
OCCURRENCES	9	13	0	3	4	5	12	10

## SPRING

SECTOR	N	NE	E	SE	S	SW	W	NW
AVERAGE HT	555	607	480	546	615	549	588	568
MAXIMUM HT	600	960	540	750	720	1250	900	750
OCCURRENCES	2	22	3	10	10	30	24	5

## SUMMER

SECTOR	N	NE	E	SE	S	SW	W	NW
AVERAGE HT	675	668	483	475	509	503	527	626
MAXIMUM HT	900	1050	570	600	750	900	900	1050
OCCURRENCES	2	8	6	6	36	28	17	17

## FALL

SECTOR	N	NE	E	SE	S	SW	W	NW
AVERAGE HT	618	632	720	556	641	502	543	615
MAXIMUM HT	1050	1050	1050	680	1260	750	900	1200
OCCURRENCES	18	31	9	10	28	26	75	37

BLH are obtained from Acoustic Sounder charts.

Table 5

MONTHLY DISTRIBUTIONS OF OZONE EXCEEDANCES  
OF THE AQG DURING 1979

MONTH	WNW20	NNE39	SW37
JAN	0	0	0
FEB	0	0	0
MAR	0	0	0
APR	3 (0.4)	0	0
MAY	6 (0.8)	0	12 (1.6)
JUN	44 (6.3)	3 (0.5)	5 (7.3)
JUL	31 (4.3)	30 (4.2)	12 (6.3)
AUG	8 (1.0)	0	0
SEP	4 (0.7)	1 (0.1)	9 (1.5)
OCT	0	0	0
NOV	0	0	0
DEC	0	0	0

( ) Represent % of the time that Ozone exceedances occurred.

Table 6

## PERCENTAGE OF VALID DATA SEASONALLY AND ANNUALLY - 1979

	SW37		NNE39		NO7	
	NO2	NO	NO2	NO	NO2	NO
WINTER	71.9	85.3	86.3	86.4	83.2	83.7
SPRING	81.9	85.4	72.5	86.4	79.5	81.5
SUMMER	13.1	13.8	89.9	91.9	34.5	35.6
FALL	17.1	33.1	91.2	92.9	13.1	13.3
ANNUAL	46.0	54.4	85.0	89.4	52.6	53.5

Table 7  
PRECIPITATION TRACE METAL CONCENTRATIONS -- NEHP NETWORK

	Mean	Standard Deviation	Minimum	Maximum
Ca	.710	.650	.04	3.32
Cd	.001	.006	.00	.05
Cu	.012	.012	.00	.06
Fe	.096	.127	.00	.60
K	.124	.139	.03	1.00
Mg	.196	.196	.02	1.12
Na	.258	.364	.01	2.50
Ni	.003	.031	.00	.27
Pb	.012	.006	.00	.04
Zn	.194	.519	.00	2.80
Mn	.010	.005	.00	.02

Concentrations are in PPM

Table 8

Annual Airborne Particulate Matter Concentration ( $\mu\text{g}/\text{m}^3$ )  
according to Wind Direction

	S	N	C	ALL
NO <sub>3</sub>	2.2 (48)	1.7 (44)	2.4 (14)	2.1
SO <sub>4</sub>	5.9 (50)	3.9 (44)	4.4 (14)	5.3
TSP*	46 (58)	43 (69)	29 (23)	45
Ca	.49 (34)	.49 (39)	.39 (13)	.53
Hg	.27 (34)	.21 (39)	.15 (13)	.21
Fl	.144 (32)	.057 (36)	.112 (13)	.09
BaP	.083 (32)	.030 (35)	.051 (13)	.05
BkF	.062 (32)	.037 (36)	.043 (13)	.05
B(ghi)P	.182 (32)	.112 (36)	.158 (13)	.15
Be	.035 (32)	.013 (36)	.024 (13)	.02
TC	4.8 (32)	4.2 (35)	4.3 (13)	4.5
FC	1.8 (32)	1.1 (35)	2.3 (13)	1.3

Fl - Flouranthene

BkF - Benzo(k)Fluoranthene

Be - Perylene

BaP - Benzo(a)Pyrene

B(ghi)P - Benzo(ghi)Pyrene

TC - Total Carbon

FC - Free Carbon

\* Data collected by 13 NEMP hi-vol samplers

( ) Number of samples

'S' Most frequent direction was from the SW to SE sector

'N' most frequent direction was from the NW to NE sector

'C' calm wind - average speed &lt; 6 km/hr

Table 9

ESTIMATED AIR QUALITY CRITERIA (AQC) BASED ON REGULATION 15  
OF THE ENVIRONMENTAL PROTECTION ACT (1971)

PARAMETER	AQC ( $\mu\text{g}/\text{m}^3$ )
B	30
Be	.01
* Ca	15
Cd	2
Cr	10
Cu	50 &
** F	2
Fe	3
*** Mg	20
Mn	50 &
Ni	2
Pb	5
Zn	30
TSP	120
SO <sub>4</sub> (SULPHURIC ACID)	30
NO <sub>3</sub> (NITRIC ACID)	30

\* Ca expressed as Ca/CaO

\*\* F expressed as Total Fluorides (gaseous and particulate)

\*\*\* Mg expressed as Mg/MgO

& Value is based on medical grounds

Table 10  
PARTICULATE TRACE METAL CONCENTRATIONS -- NEMP NETWORK

	Mean	Standard Deviation	Minimum	Maximum
Al	.572	.903	.03	8.90
Cd	.001	.001	.00	.01
Cu	.068	.111	.00	.65
Fe	.449	.449	.02	2.85
Hg	.282	.343	.01	3.79
Mn	.017	.016	.00	.11
Ni	.005	.016	.00	.14
Pb	.073	.049	.00	.26
Zn	.054	.042	.01	.32
B	.007	.003	.00	.01
Ca	.902	1.630	.03	18.07
Cr	.005	.028	.00	.33

Concentrations are in ug/m3.

FIGURE 1

# MONITORING STATIONS IN NANTICOKE REGION

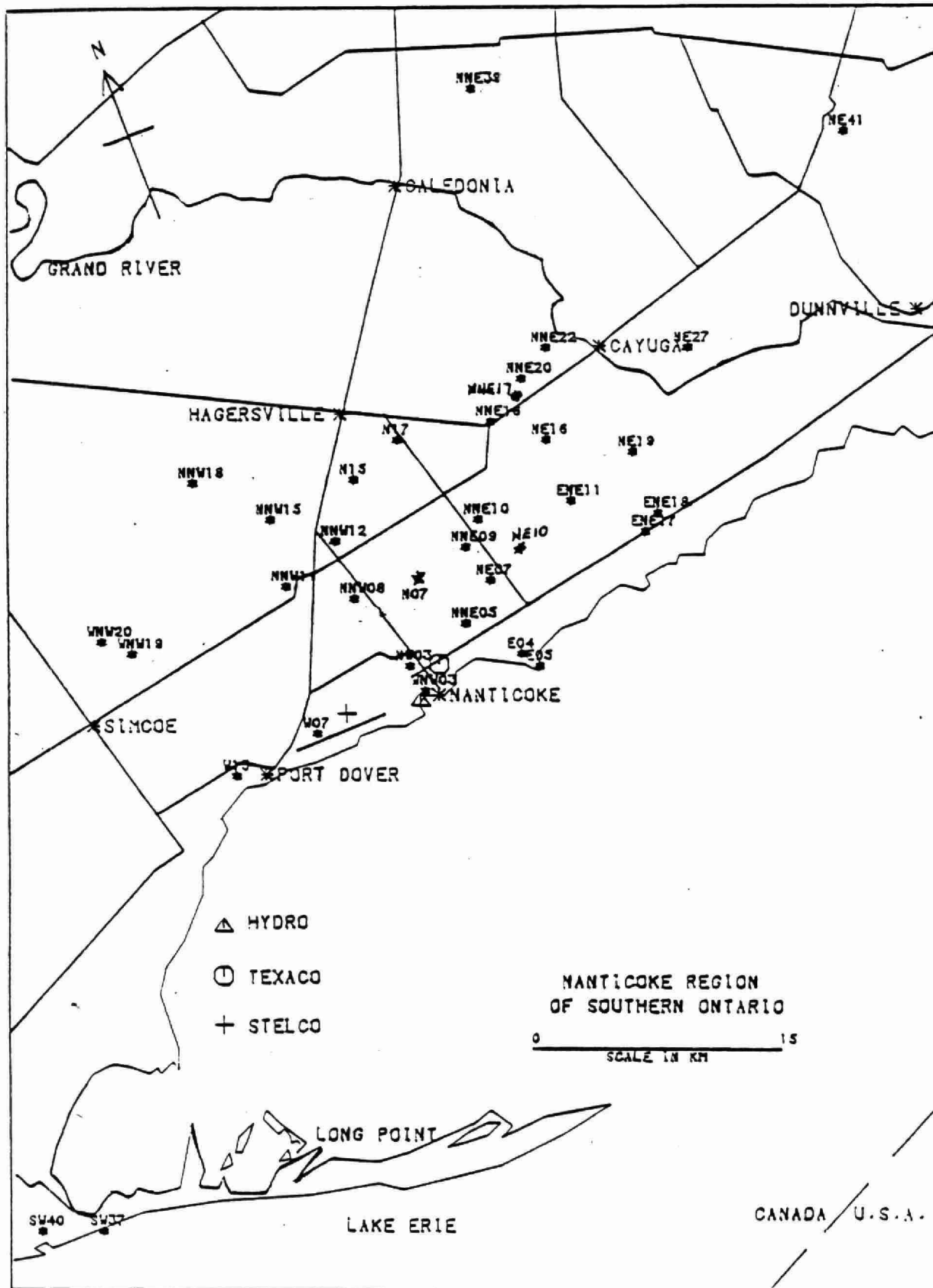
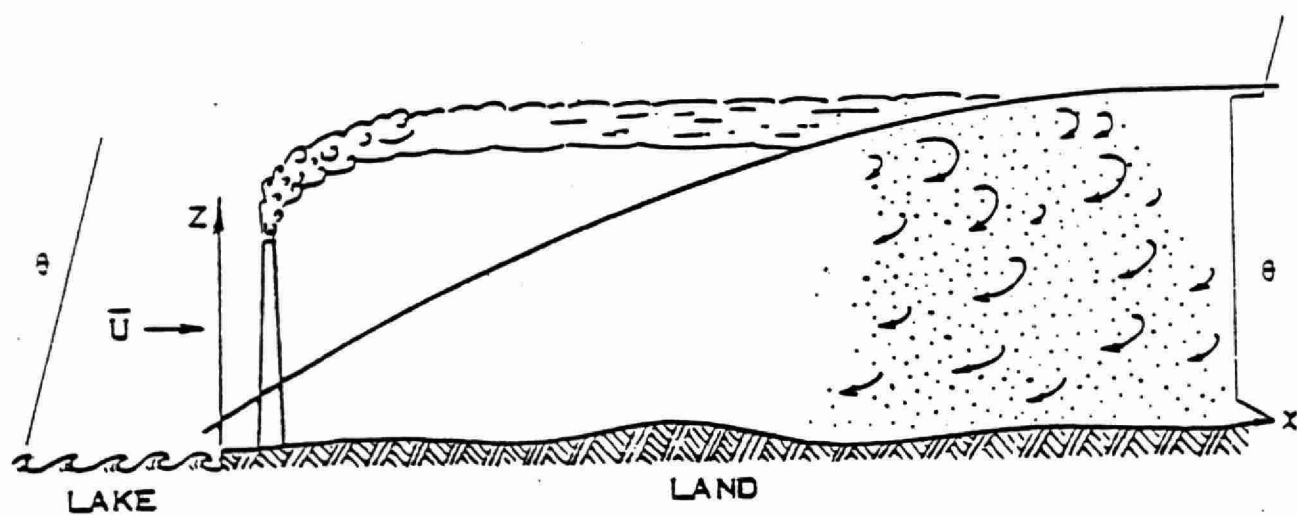


FIGURE 2 FUMIGATION DUE TO INTERNAL BOUNDARY LAYER



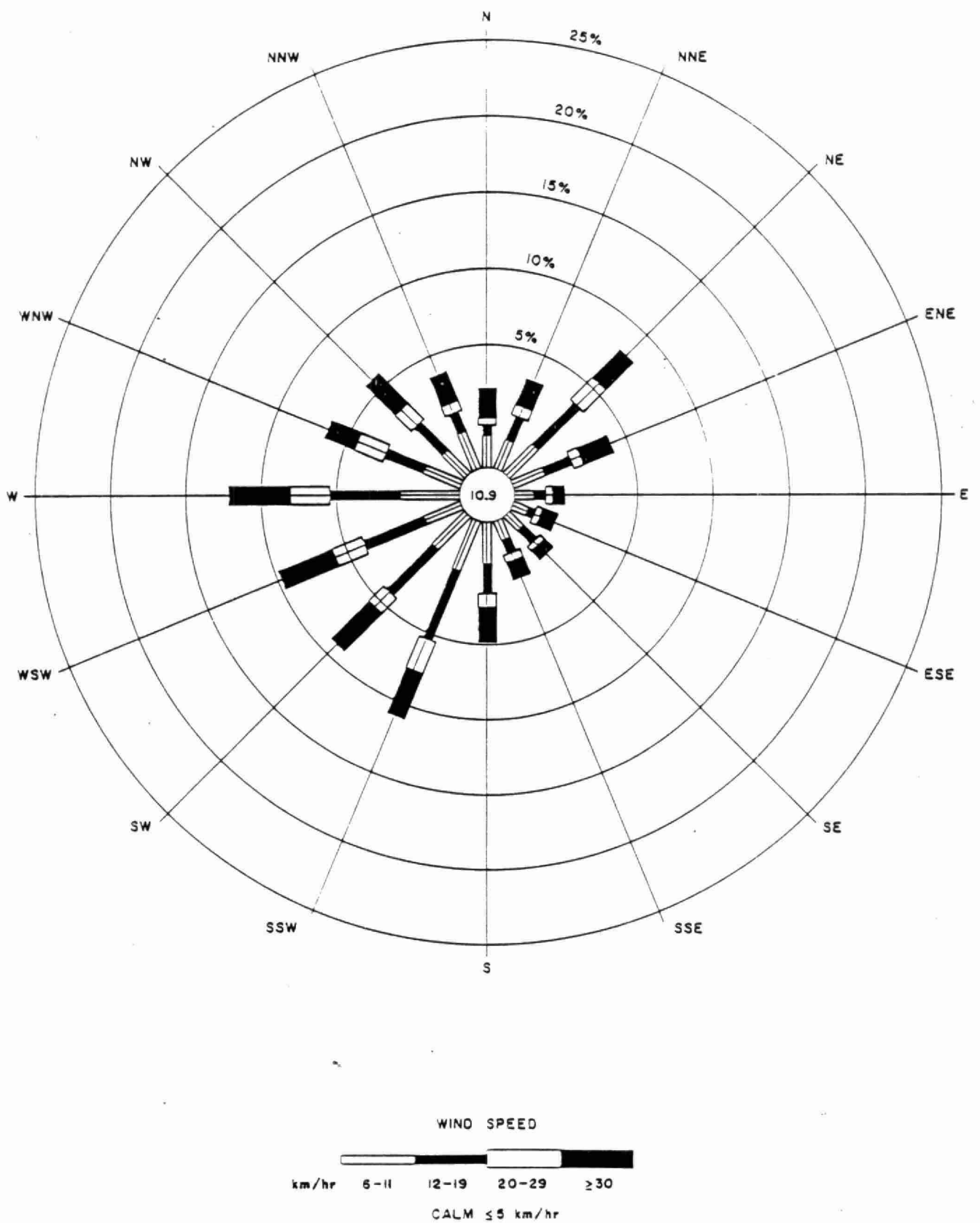


Figure 3. Annual Wind Rose for 10m Winds at Jarvis Met Tower 1975-1979.

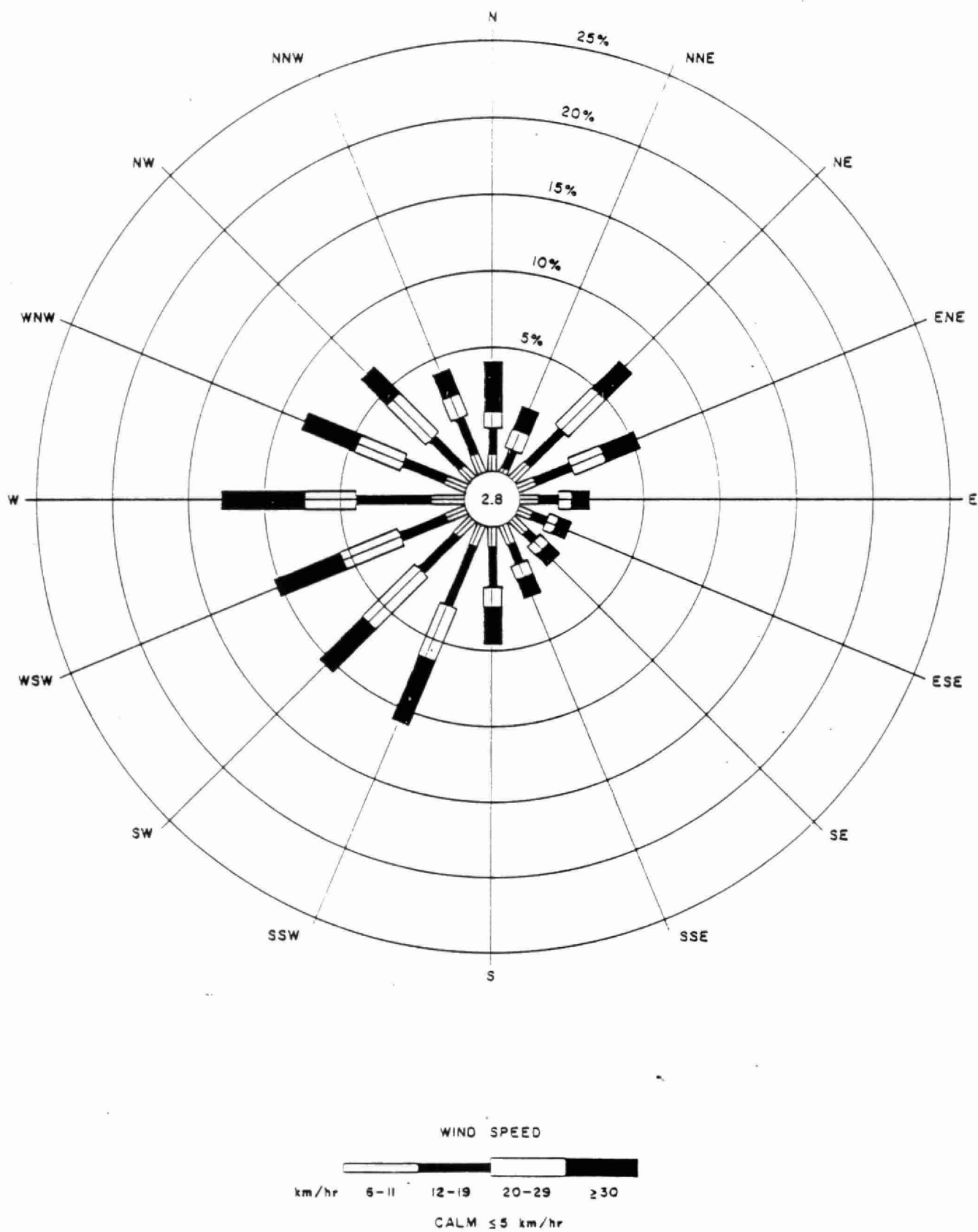


Figure 4. Annual Wind Rose for 85m Winds at Jarvis Met Tower 1975-1979.

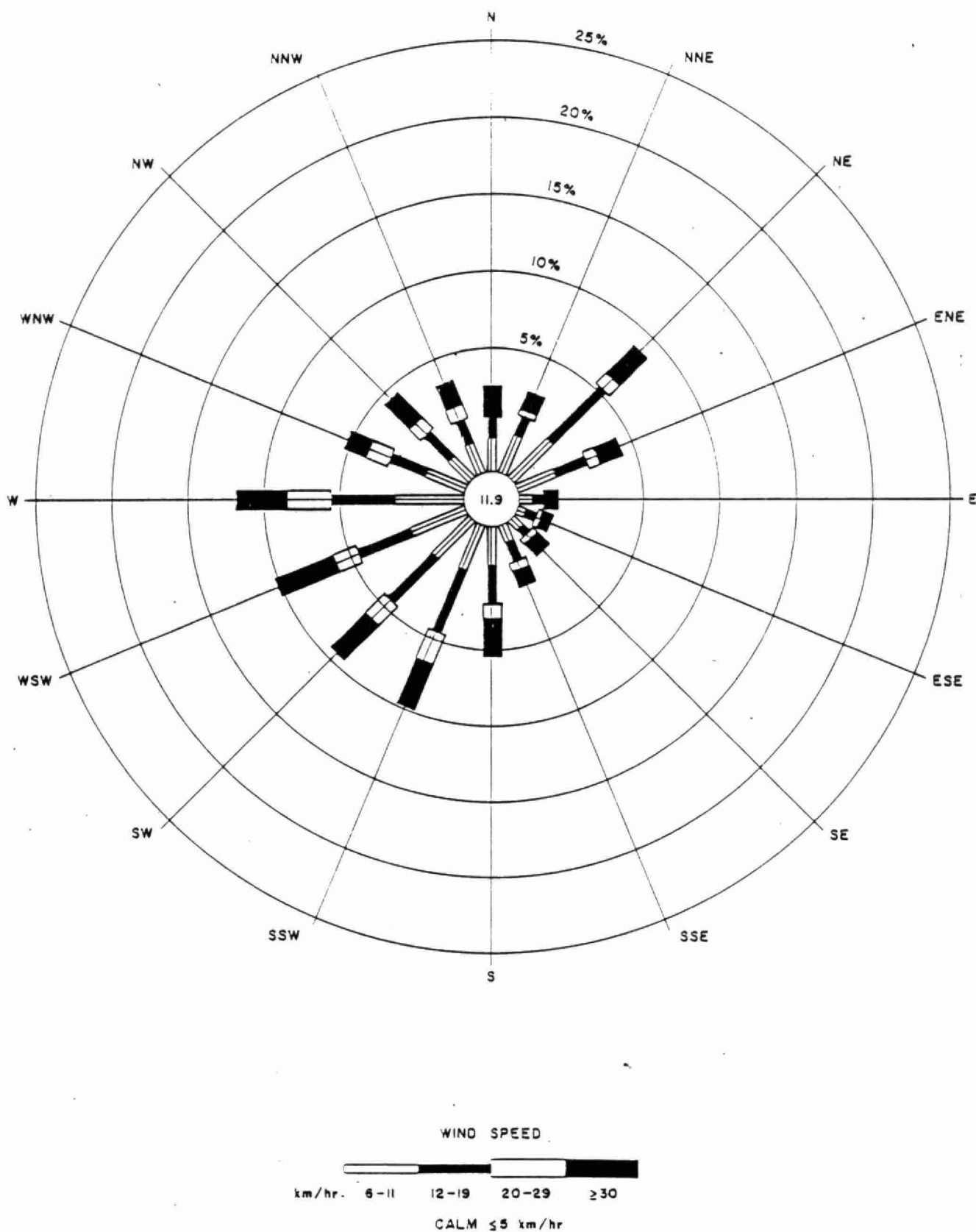


Figure 5. Fall Wind Rose for 10m Winds at Jarvis Met Tower 1975-1979.

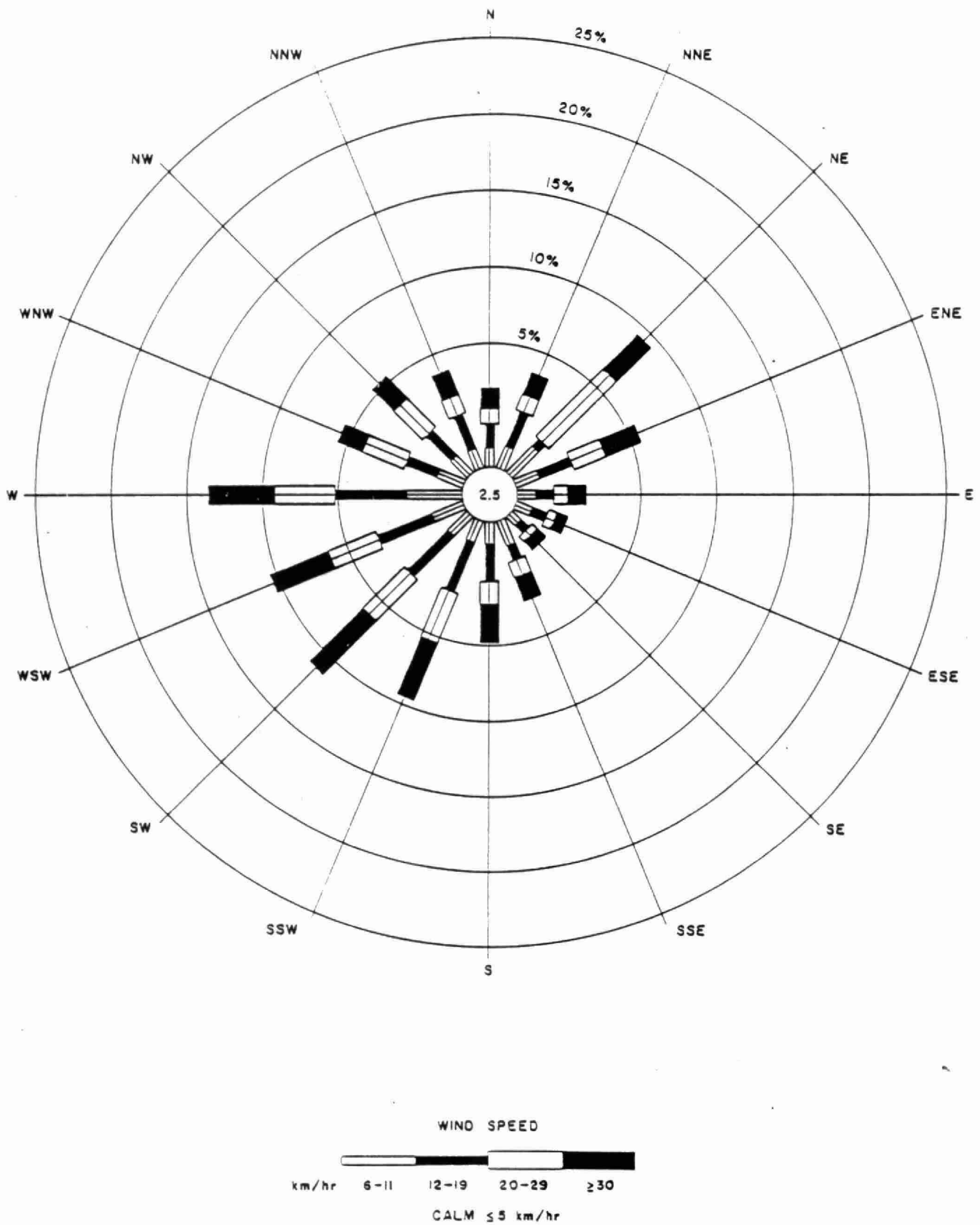


Figure 6. Fall Wind Rose for 85m Winds at Jarvis Met Tower 1975-1979.

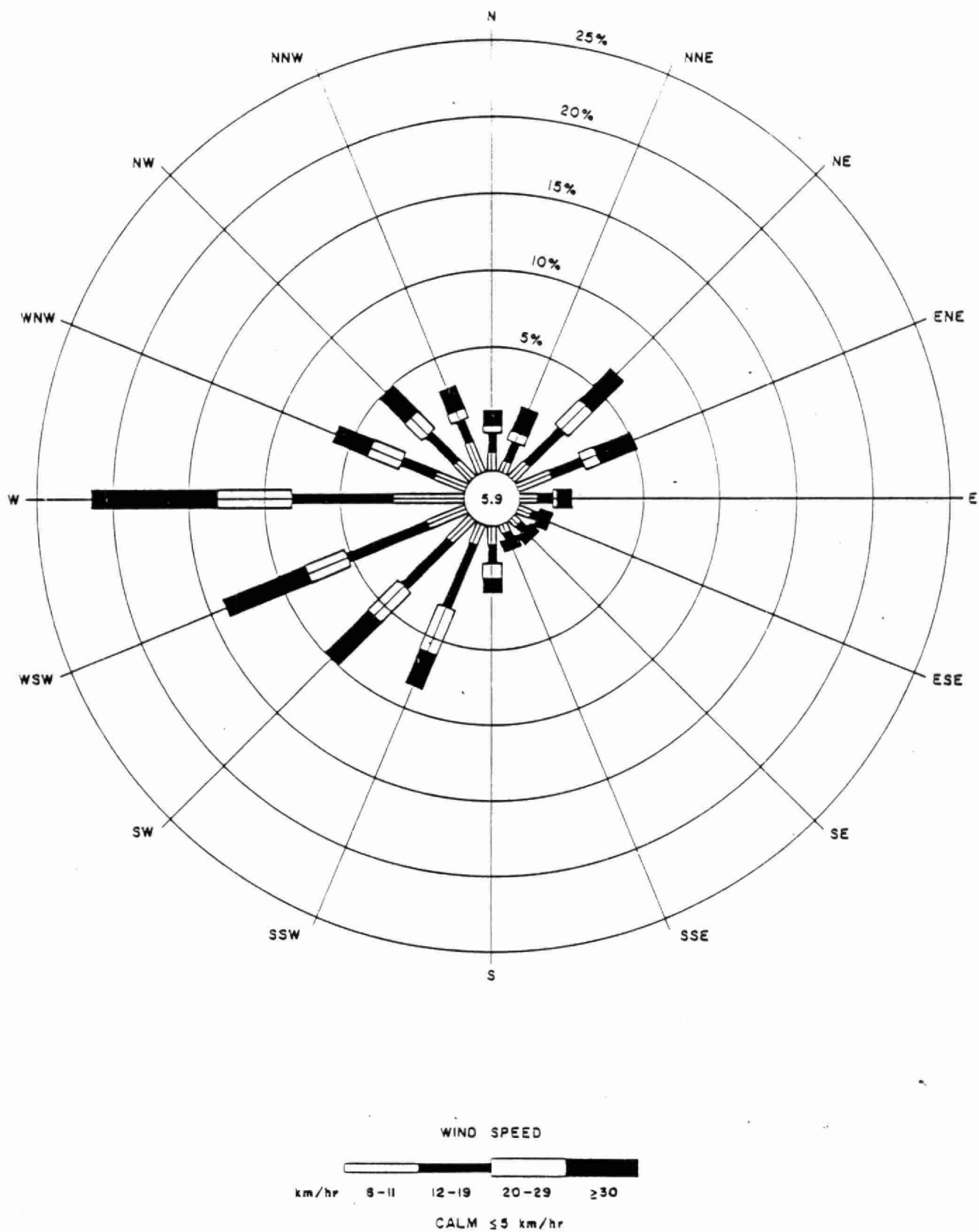


Figure 7. Winter Wind Rose for 10m Winds at Jarvis Met Tower 1975-1979.

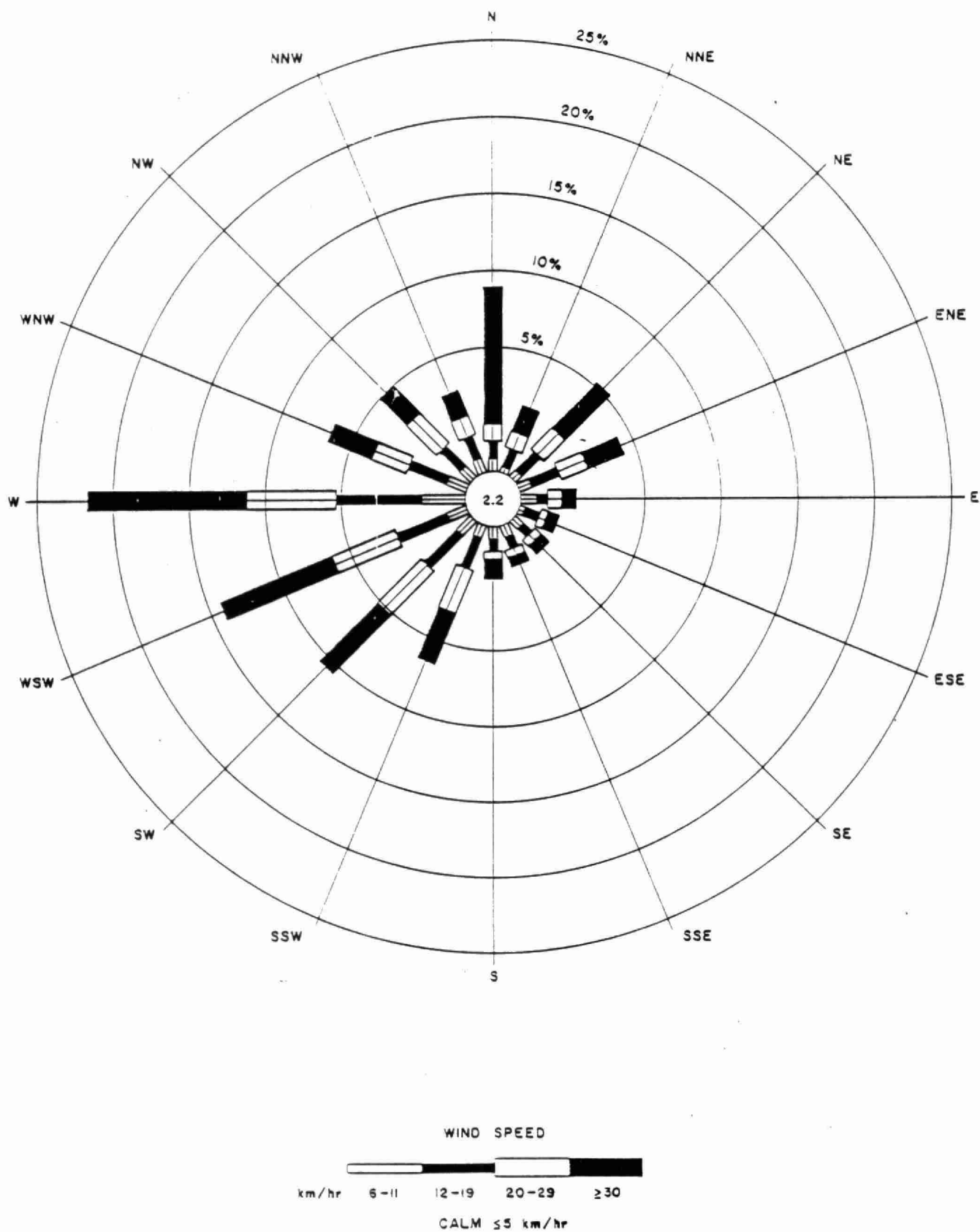


Figure 8. Winter Wind Rose for 85m Winds at Jarvis Met Tower 1975-1979.

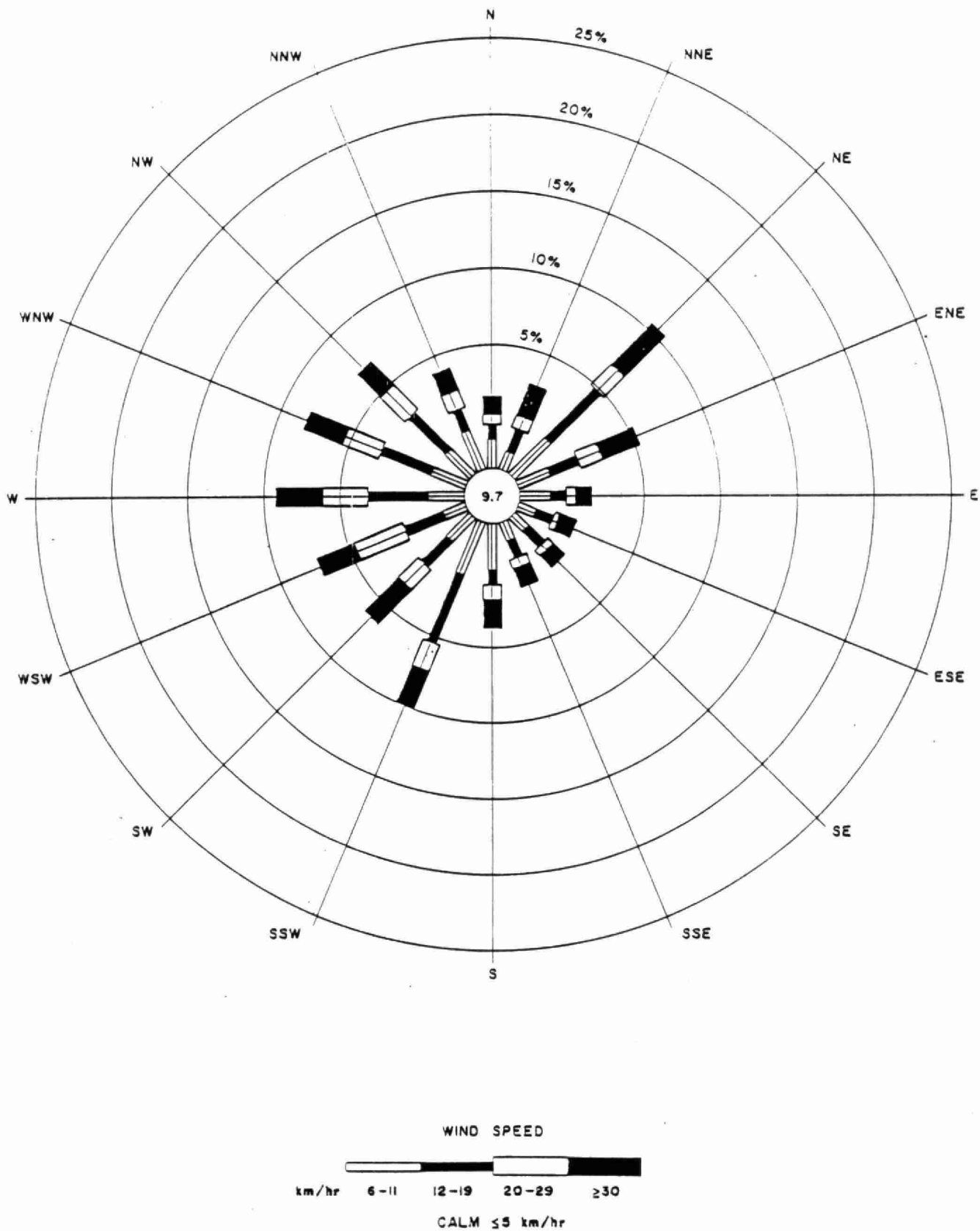


Figure 9. Spring Wind Rose for 10m Winds at Jarvis Met Tower 1975-1979.

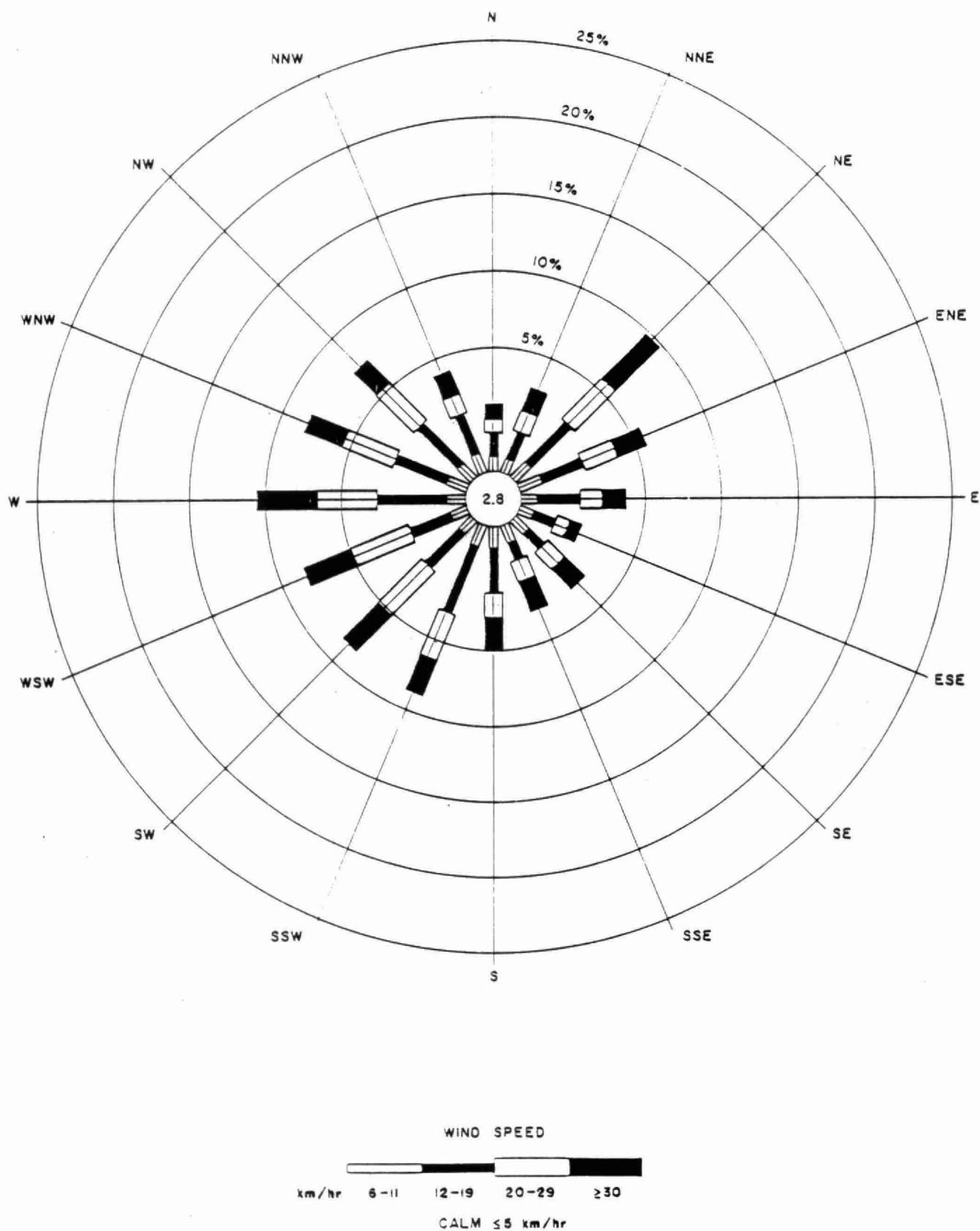


Figure 10. Spring Wind Rose for 85m Winds at Jarvis Met Tower 1975-1979.

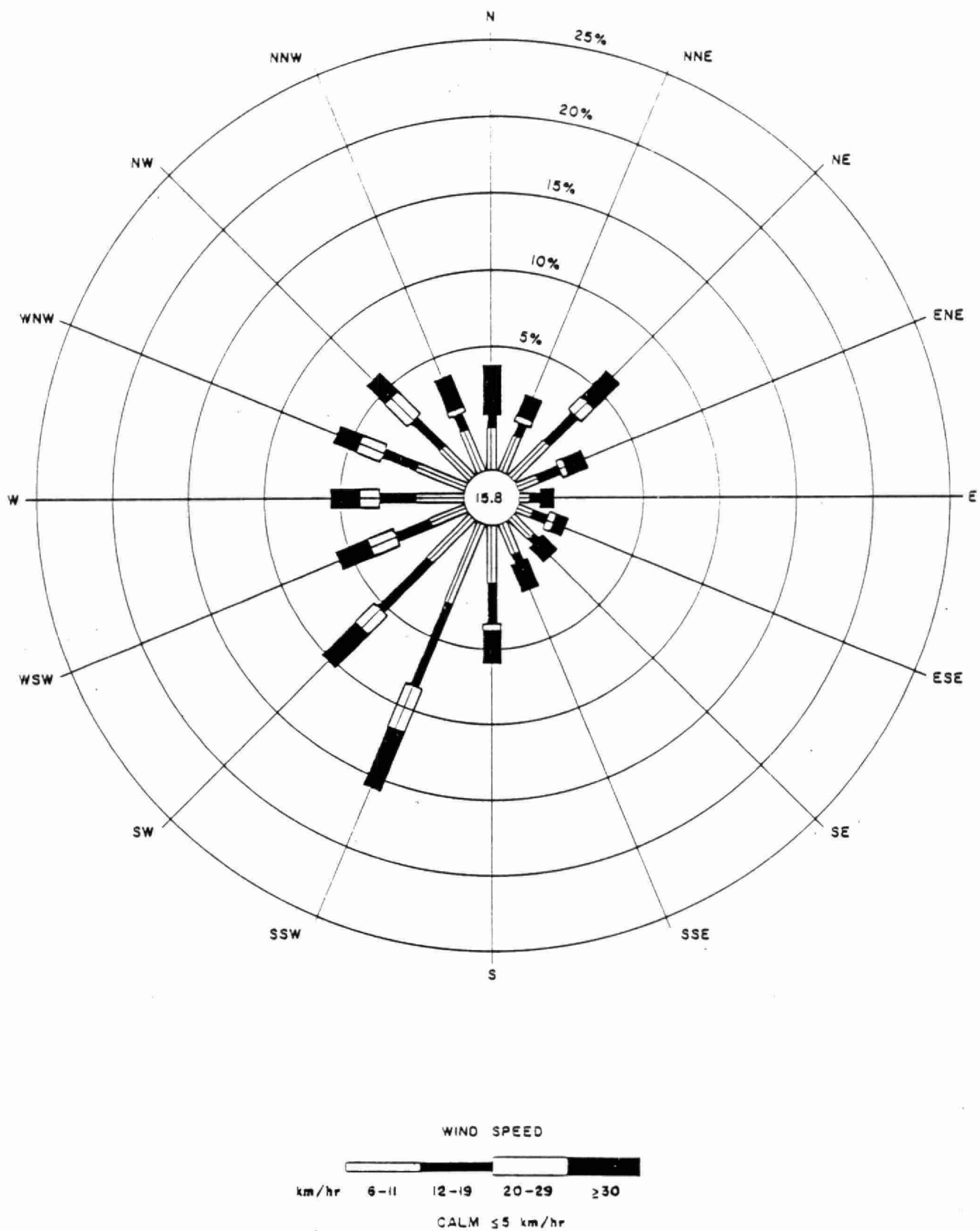


Figure 11. Summer Wind Rose for 10m Winds at Jarvis Met Tower 1975-1979

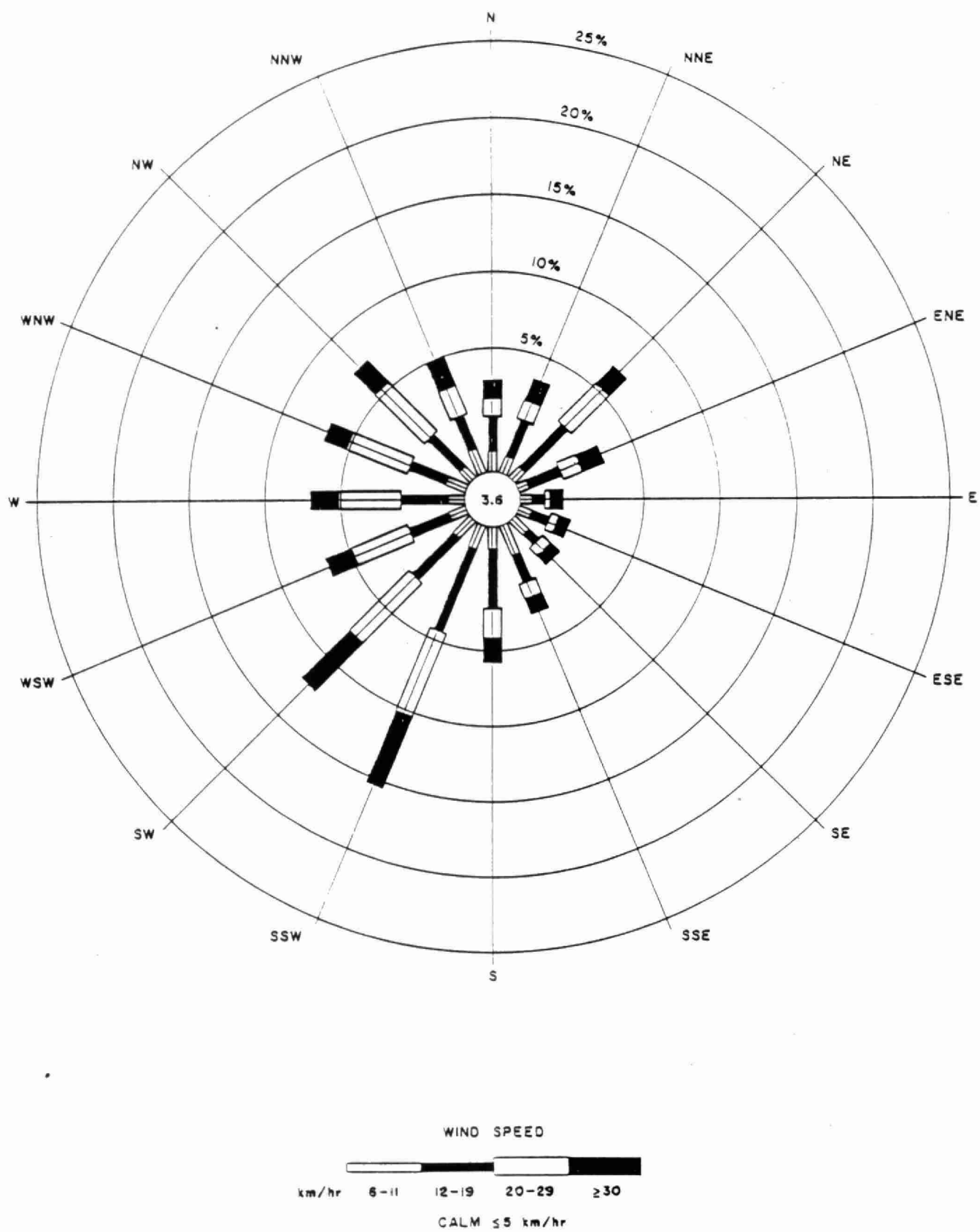


Figure 12. Summer Wind Rose for 85m Winds at Jarvis Met Tower 1975-1979

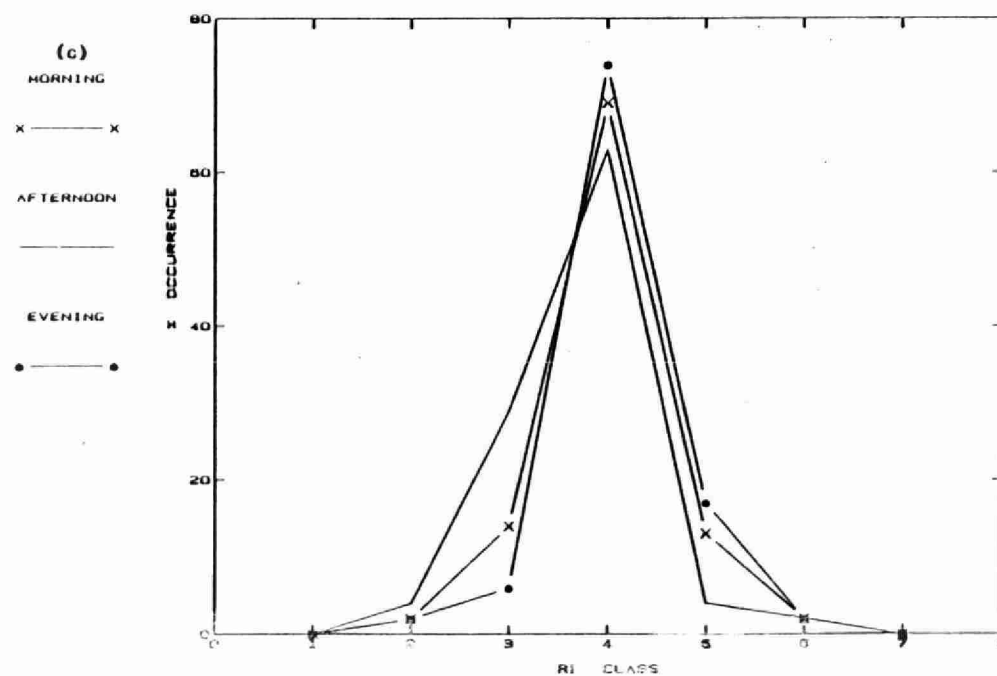
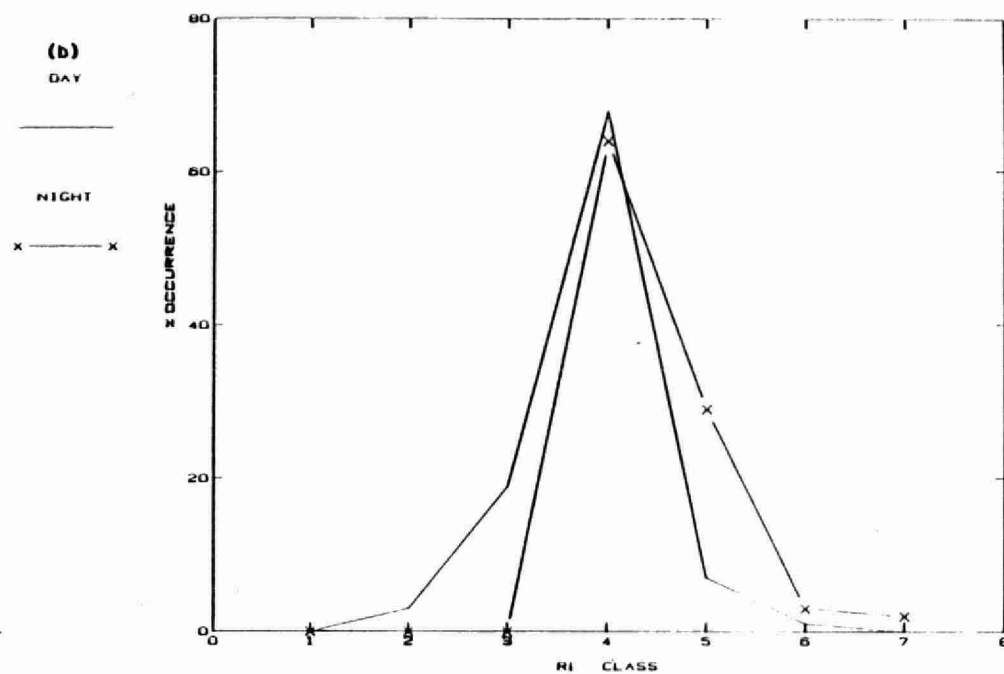
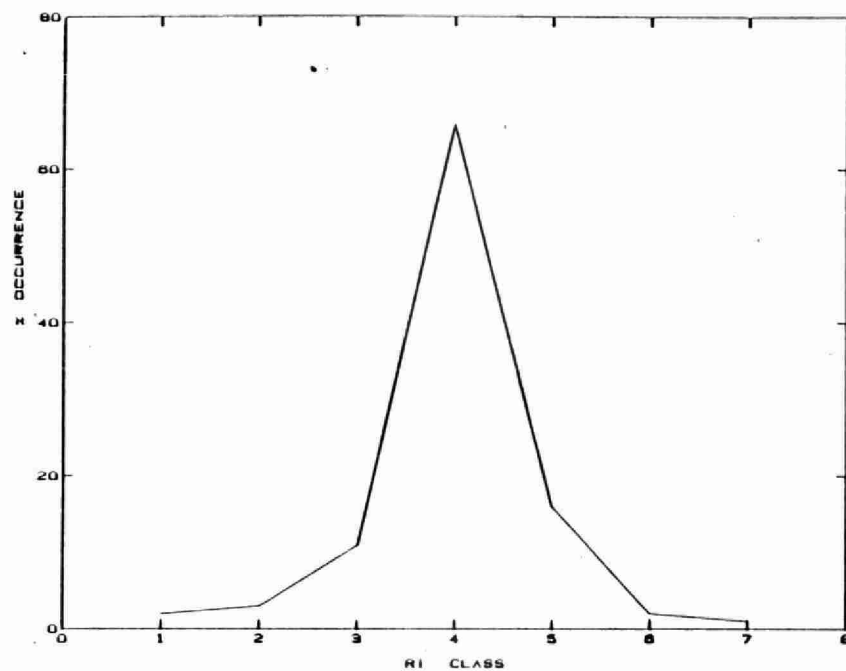


FIGURE 12. FREQUENCY DISTRIBUTION OF RI VALUES

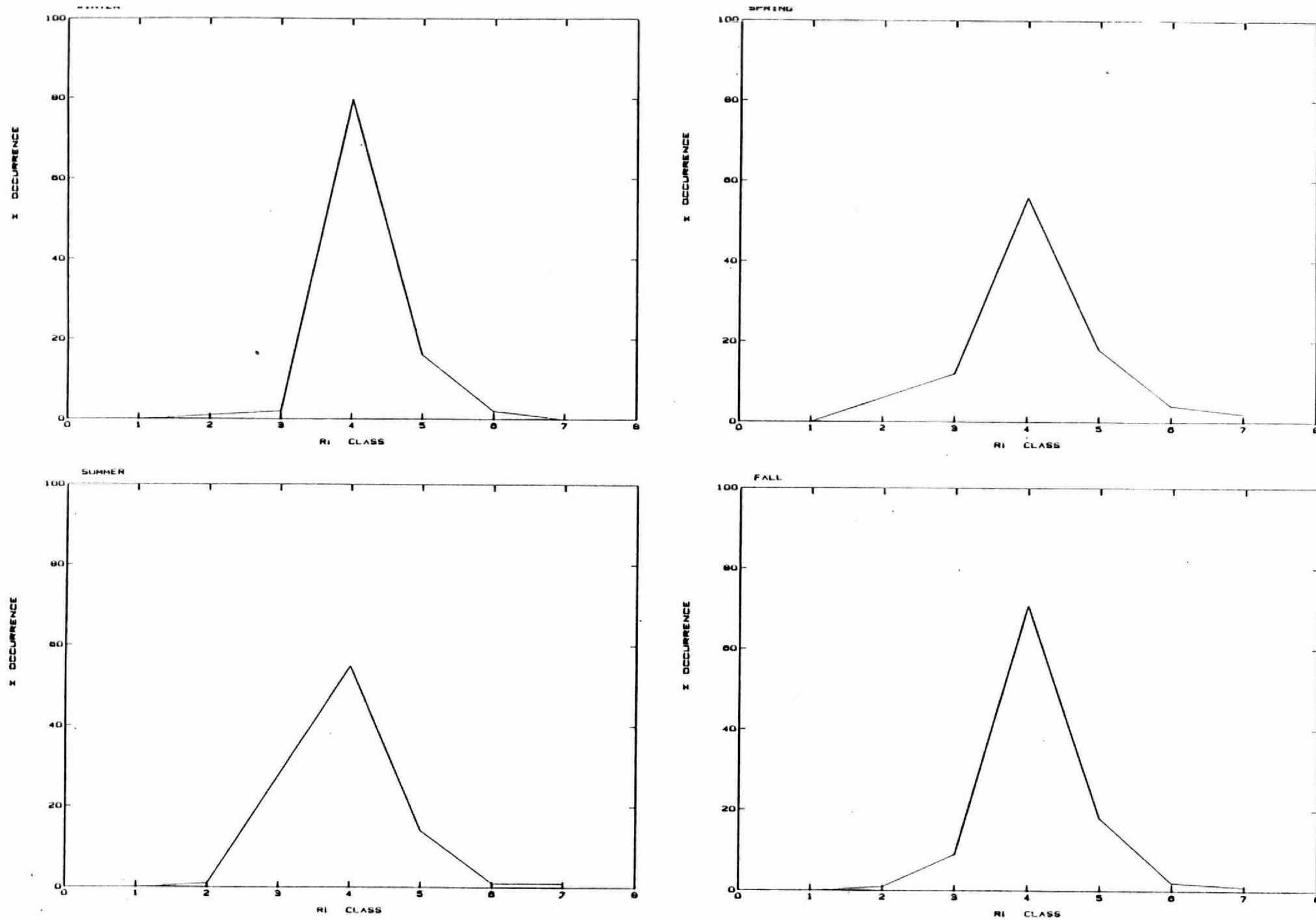


FIGURE 14 : SEASONAL FREQUENCY DISTRIBUTION OF RI VALUES.

FIGURE 15 ANNUAL DISTRIBUTION OF HOURLY AVERAGED BLH ACCORDING TO WIND DIRECTION.

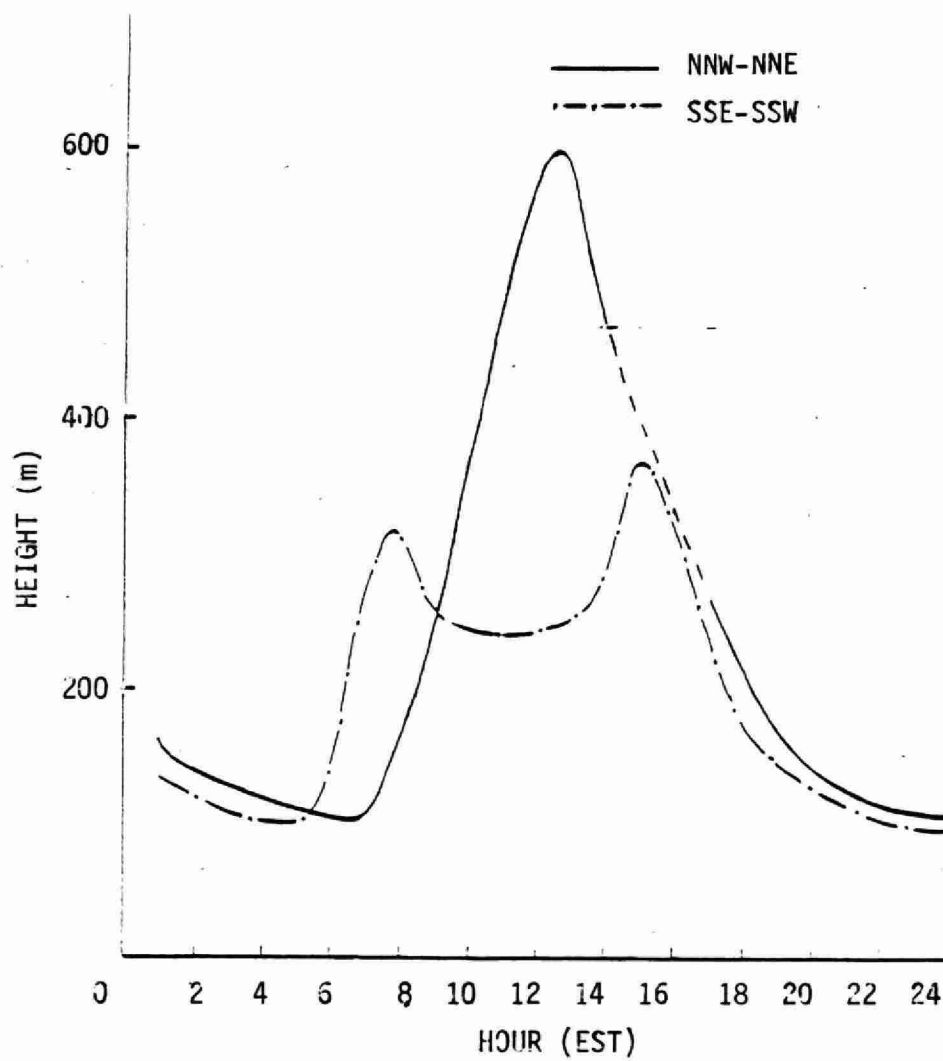
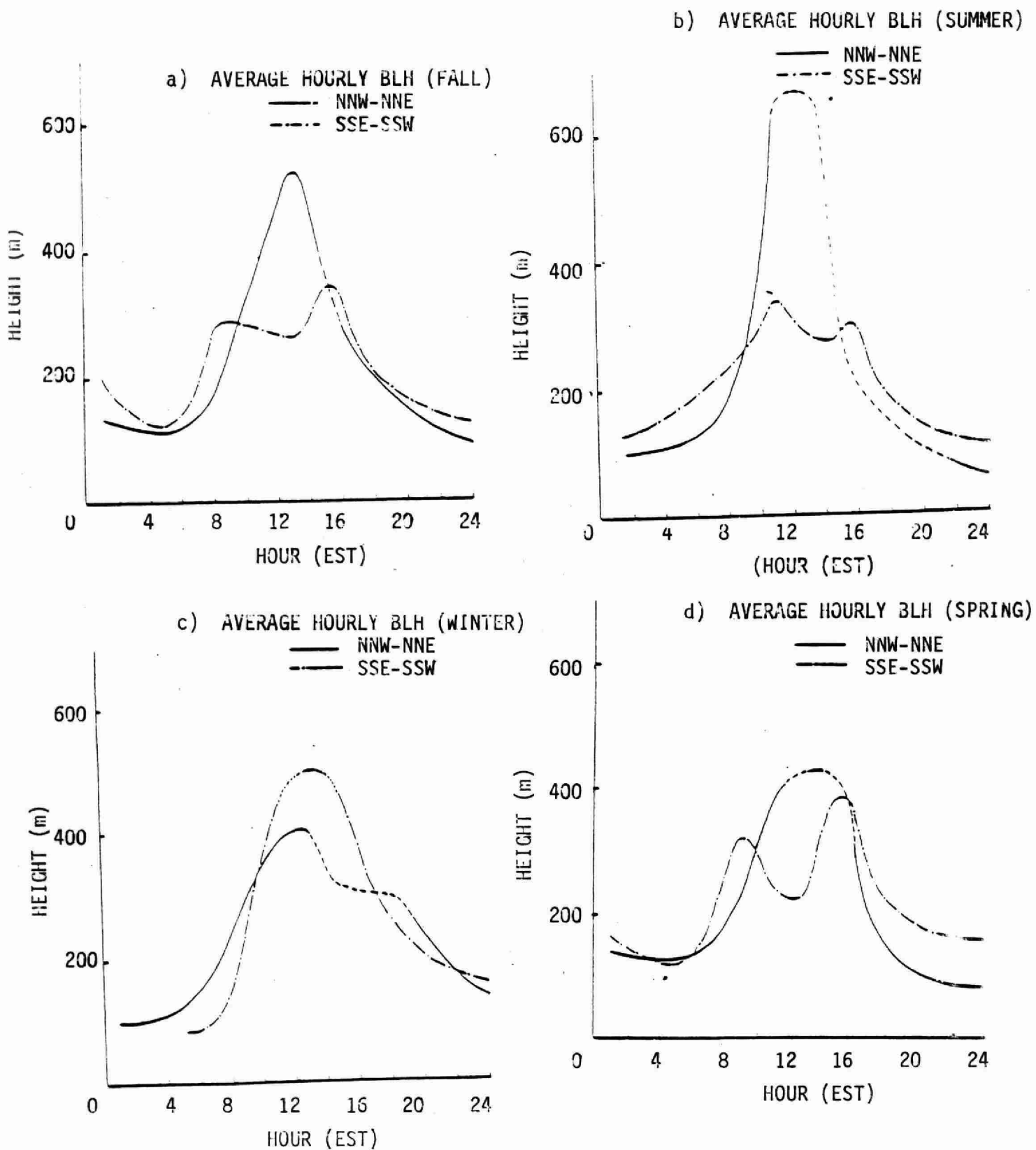
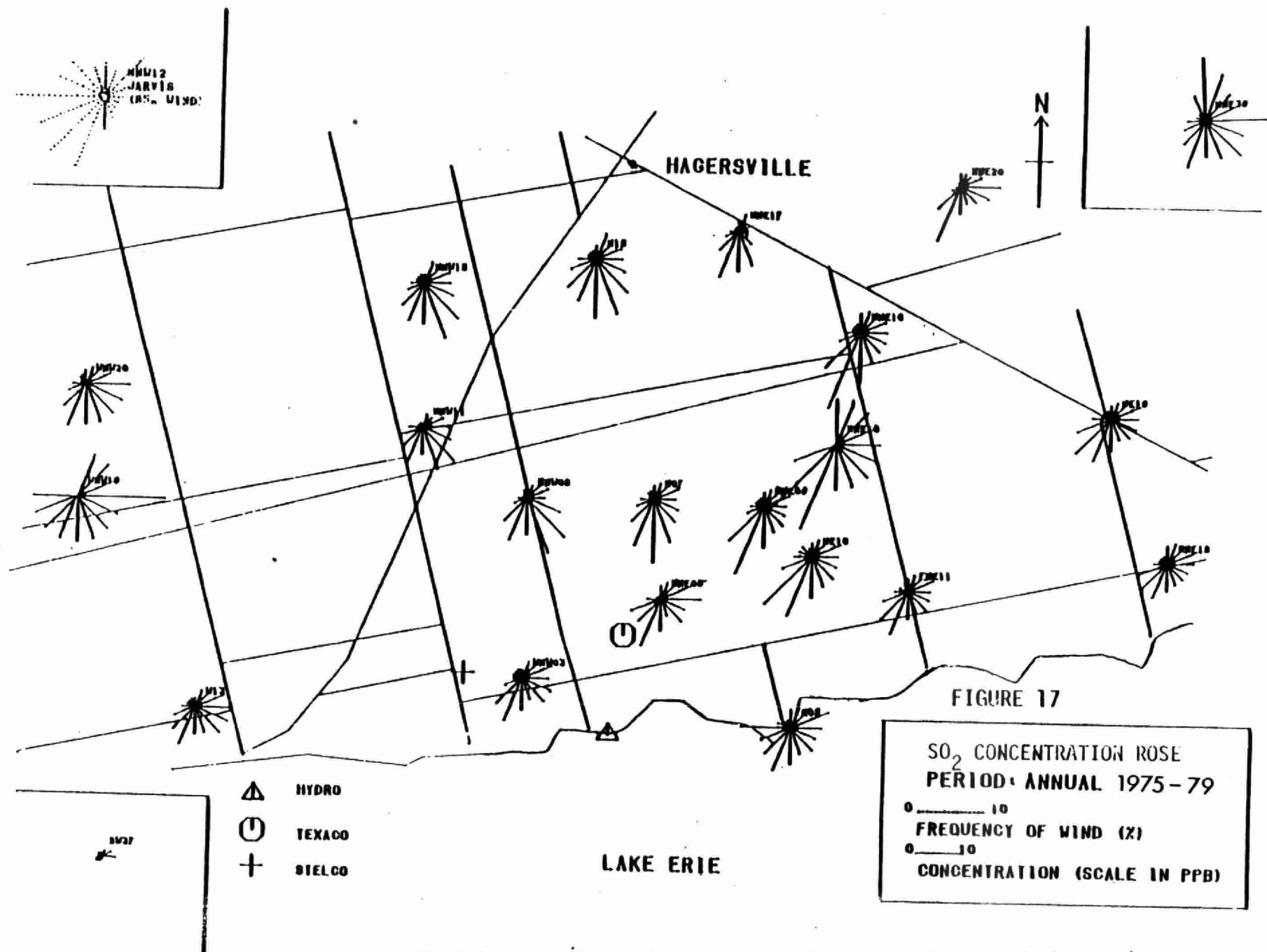


FIGURE 16 SEASONAL DISTRIBUTION OF HOURLY AVERAGED BLH ACCORDING TO WIND DIRECTION.





\*NNE10 and WNW10 - data reported in ppm and converted to ppb.

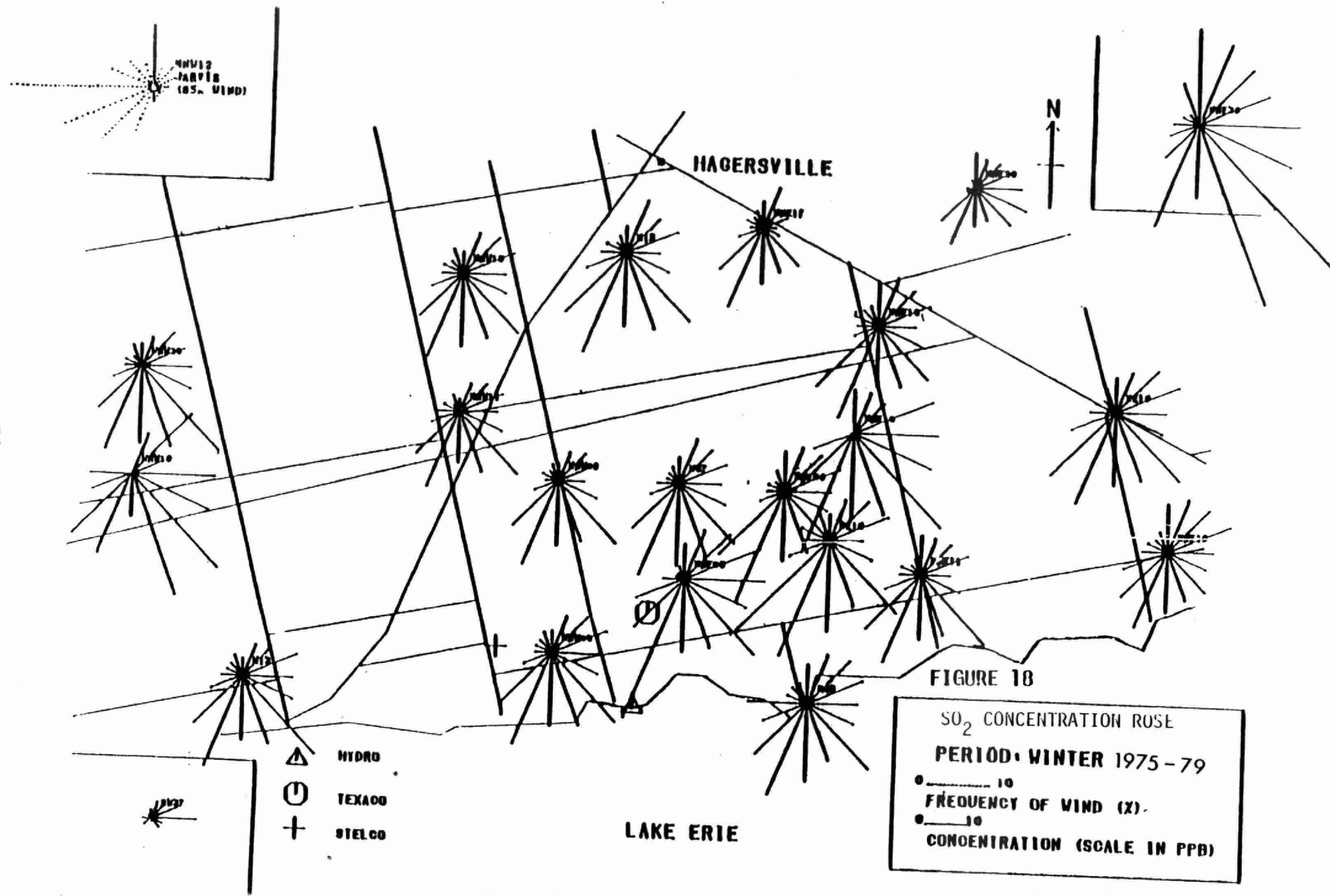
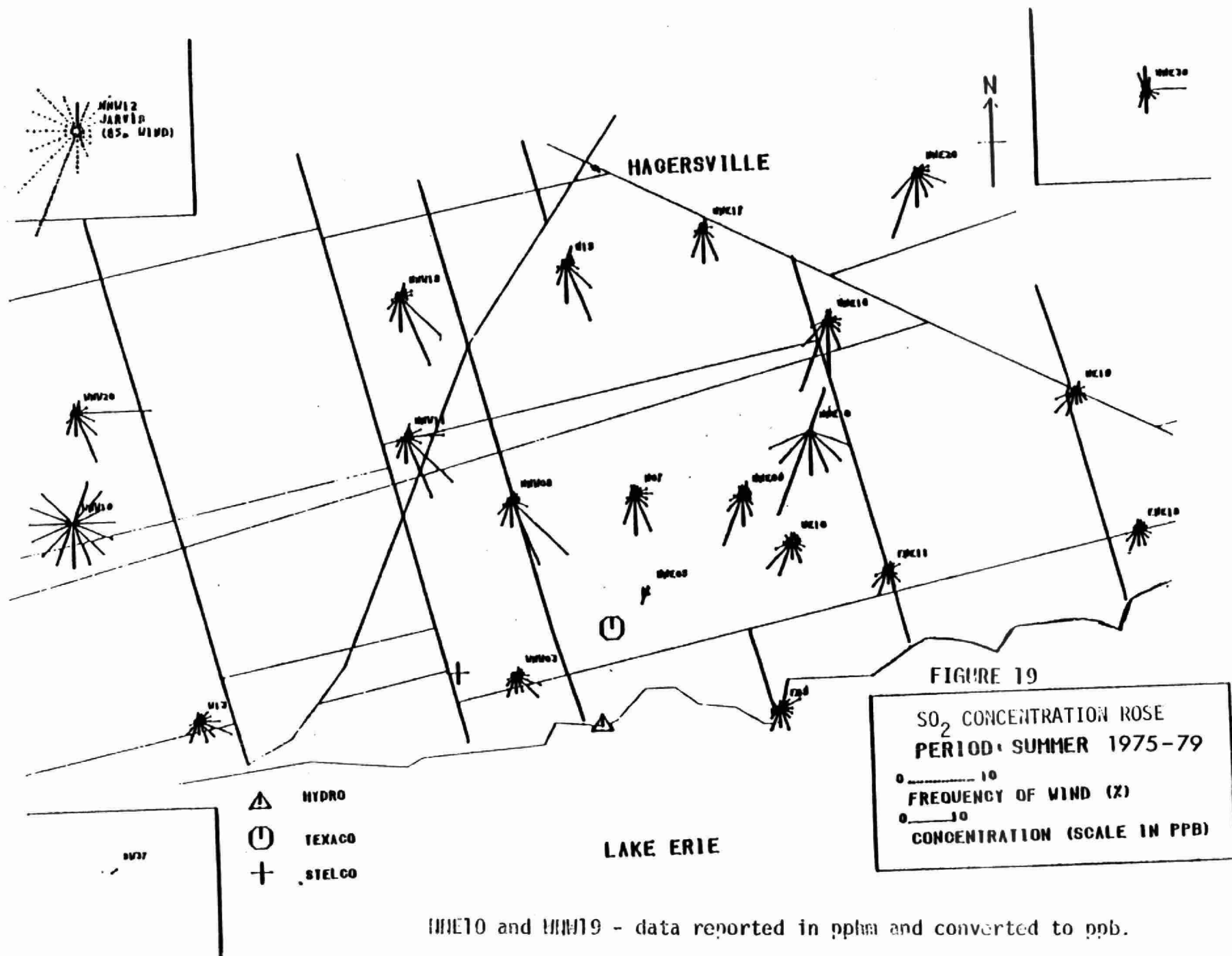
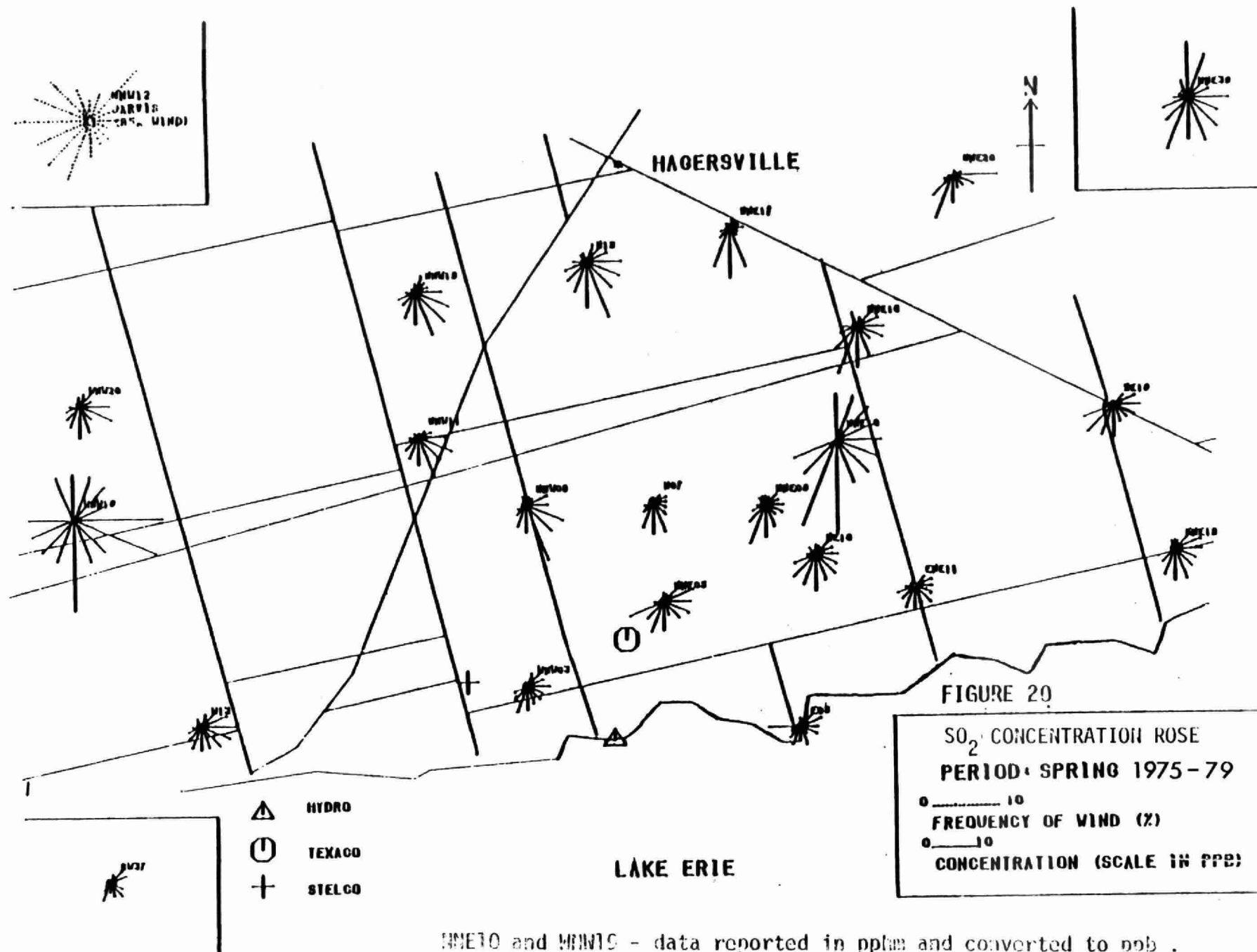


FIGURE 18  
SO<sub>2</sub> CONCENTRATION ROSE  
PERIOD: WINTER 1975-79  
● — 10  
FREQUENCY OF WIND (X)  
● — 10  
CONCENTRATION (SCALE IN PPB)

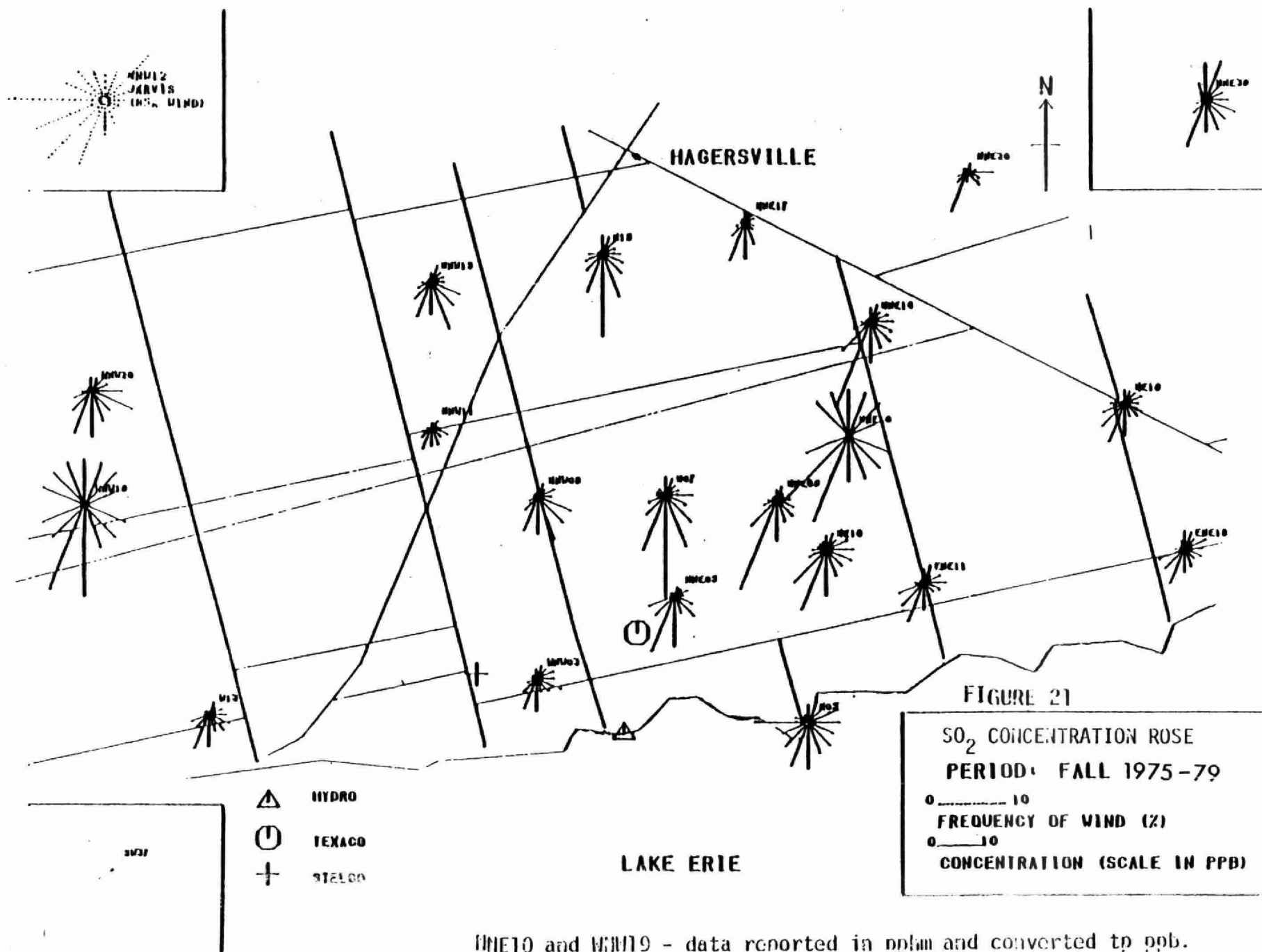
44V12 and 44V18 - data reported in ppb and converted to ppb.

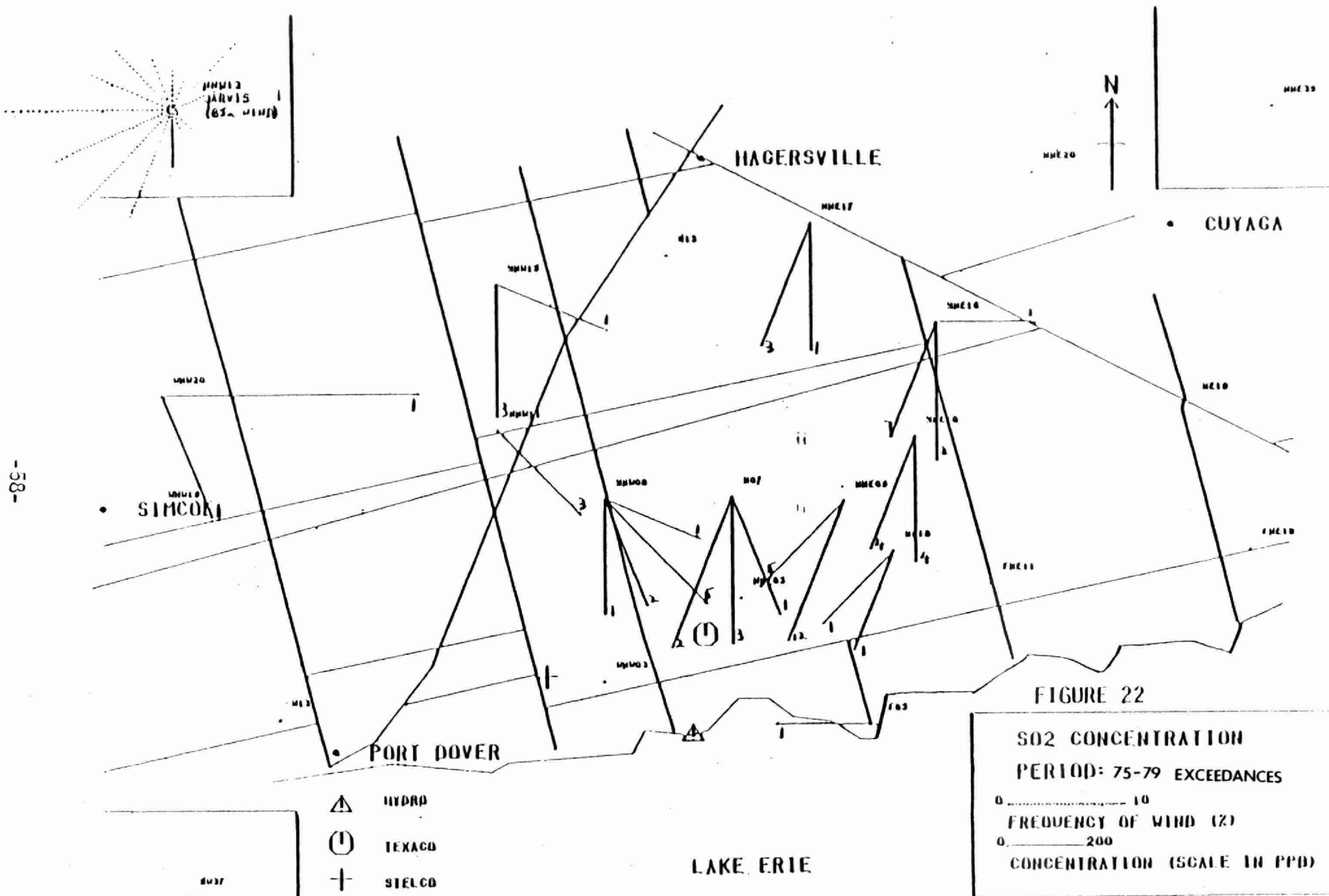


MW10 and MW19 - data reported in ppm and converted to ppb.



MMV10 and MMV19 - data reported in ppm and converted to ppb .





\* Each arm shows the average SO<sub>2</sub> concentration for that particular wind direction  
\* The number of exceedances is shown at the end of the arm



WINTER

SPRING

SUMMER

FALL

ANNUAL

EXCEEDANCES  
(calms not included)

FIGURE 23

$O_3$  CONCENTRATION ROSE

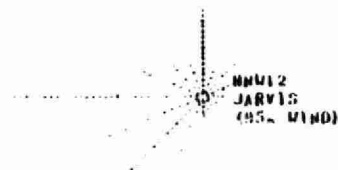
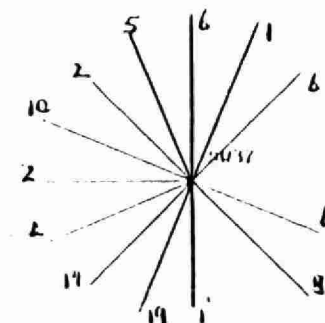
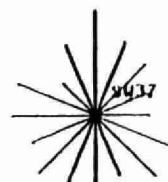
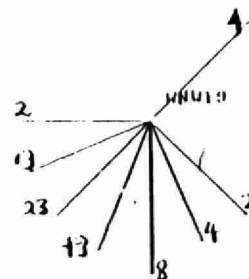
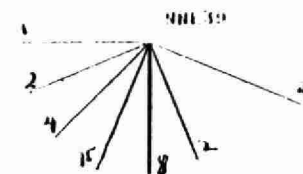
PERIOD: 1979

0 ..... 10

FREQUENCY OF WIND (Z)

0 ..... 50

CONCENTRATION (SCALE IN PPB)



☒ HYDROCARBON MONITORS  
 ☼ WELLS IN SERVICE  
 ⚙ WELLS ABANDONED  
 --- GAS LINES

JAN 1 - JUNE 12  
(SRU NOT OPERATING)

JUNE 13 - DEC 31  
(SRU OPERATING)

ANNUAL



FIGURE 25

TRS CONCENTRATION ROSE  
PERIOD: 1979

0 ..... 10

FREQUENCY OF WIND (%)

0 ..... 1

CONCENTRATION (SCALE IN PPB)



WINTER

SPRING

SUMMER

FALL

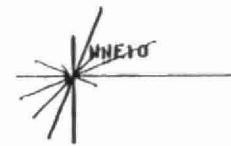


FIGURE 26

TRS CONCENTRATION ROSE  
PERIOD: 1979

0 ..... 10

FREQUENCY OF WIND (X)

0 ..... 1

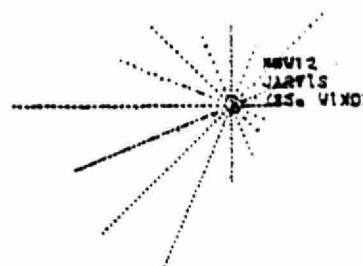
CONCENTRATION (SCALE IN PPB)



44E10



44U08



44E05

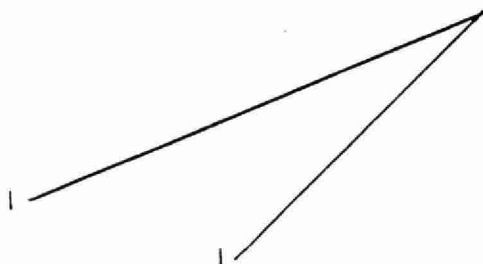
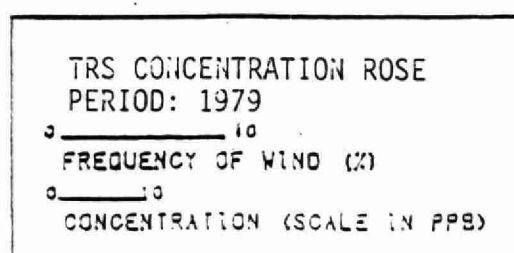


FIGURE 27



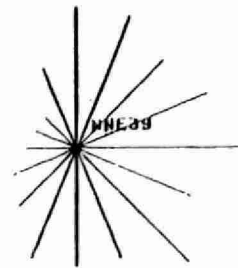
WINTER

SPRING

SUMMER

FALL

ANNUAL



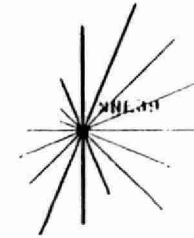
NNE39



NNE39



NNE39



NNE39



FIGURE 28

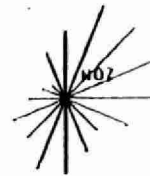
NO<sub>2</sub> CONCENTRATION ROSE  
PERIOD: 1979

0 ..... 10

FREQUENCY OF WIND (%)

0 ..... 10

CONCENTRATION (SCALE IN PPB)



SW37



SW37

N07

N07

N07



SW37

SW37

SW37



NNE12  
JARVIS  
(85% WIND)



NNE12  
JARVIS  
(85% WIND)



NNE12  
JARVIS  
(85% WIND)



NNE12  
JARVIS  
(85% WIND)

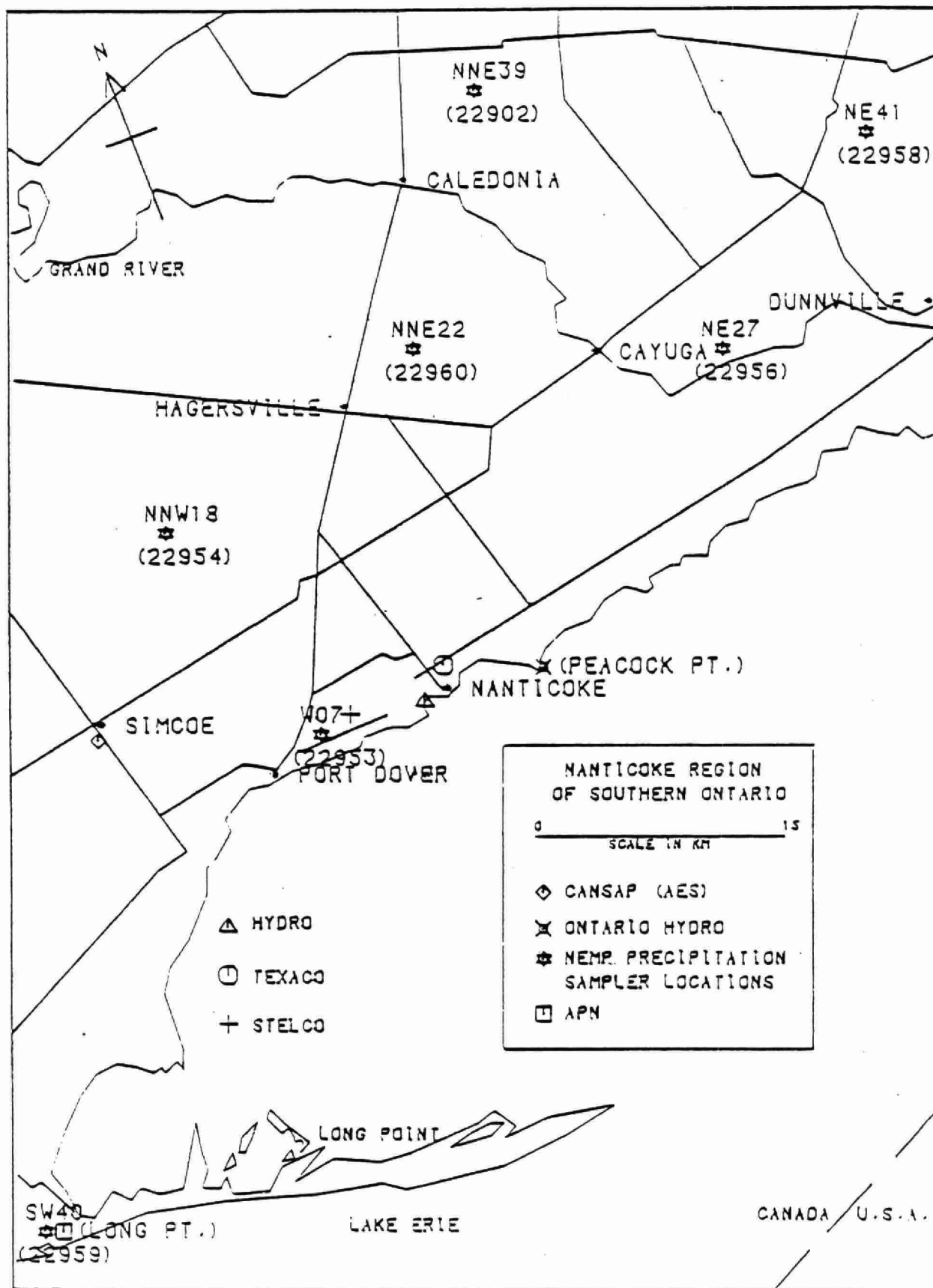


NNE12  
JARVIS  
(85% WIND)

\* • LESS THAN 75% VALID DATA

FIGURE 29

# PRECIPITATION SAMPLING NETWORK



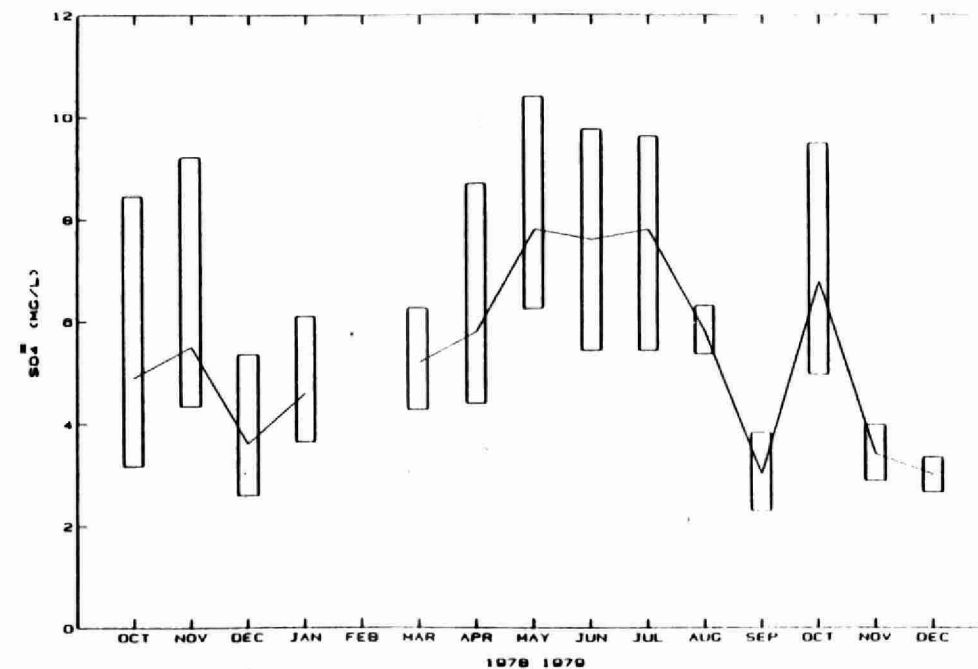
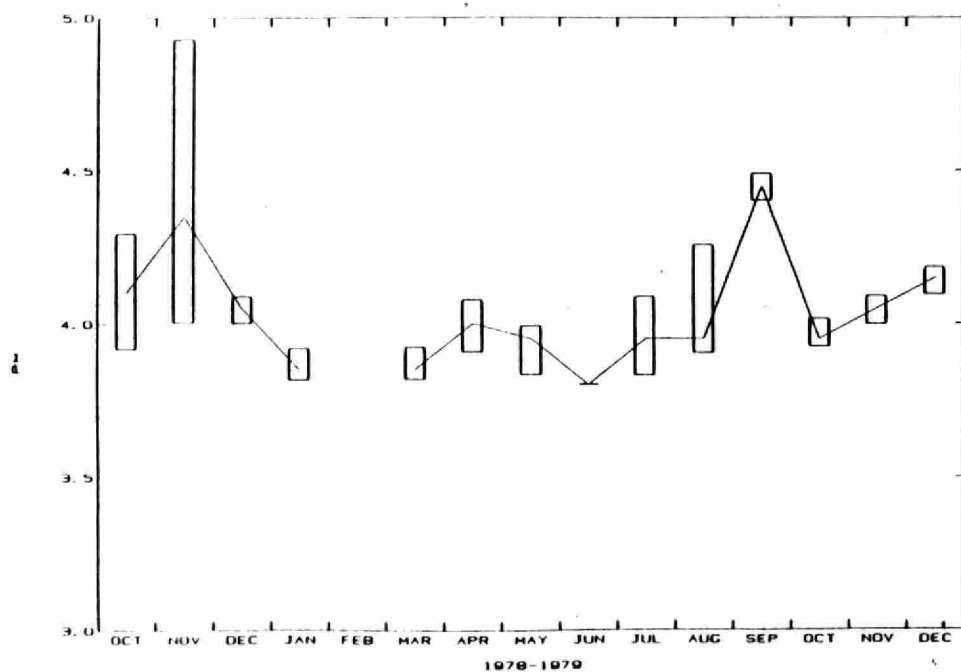
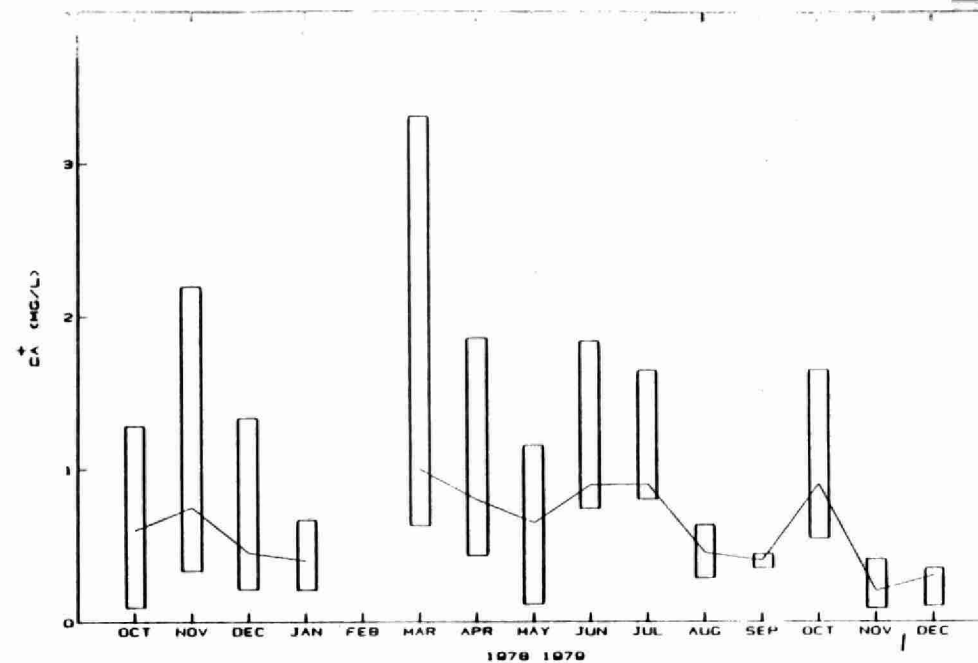
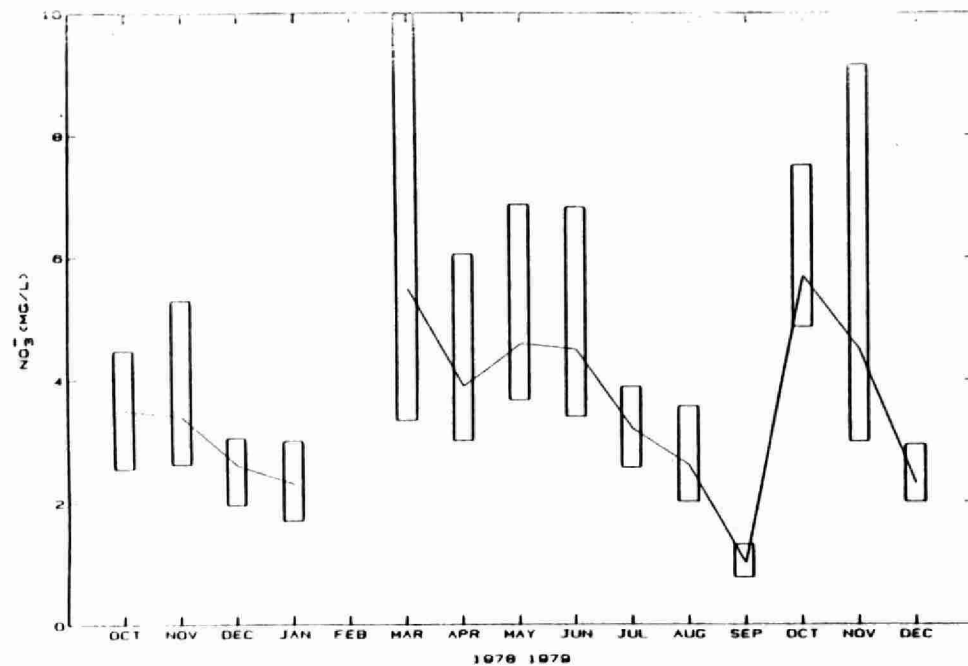
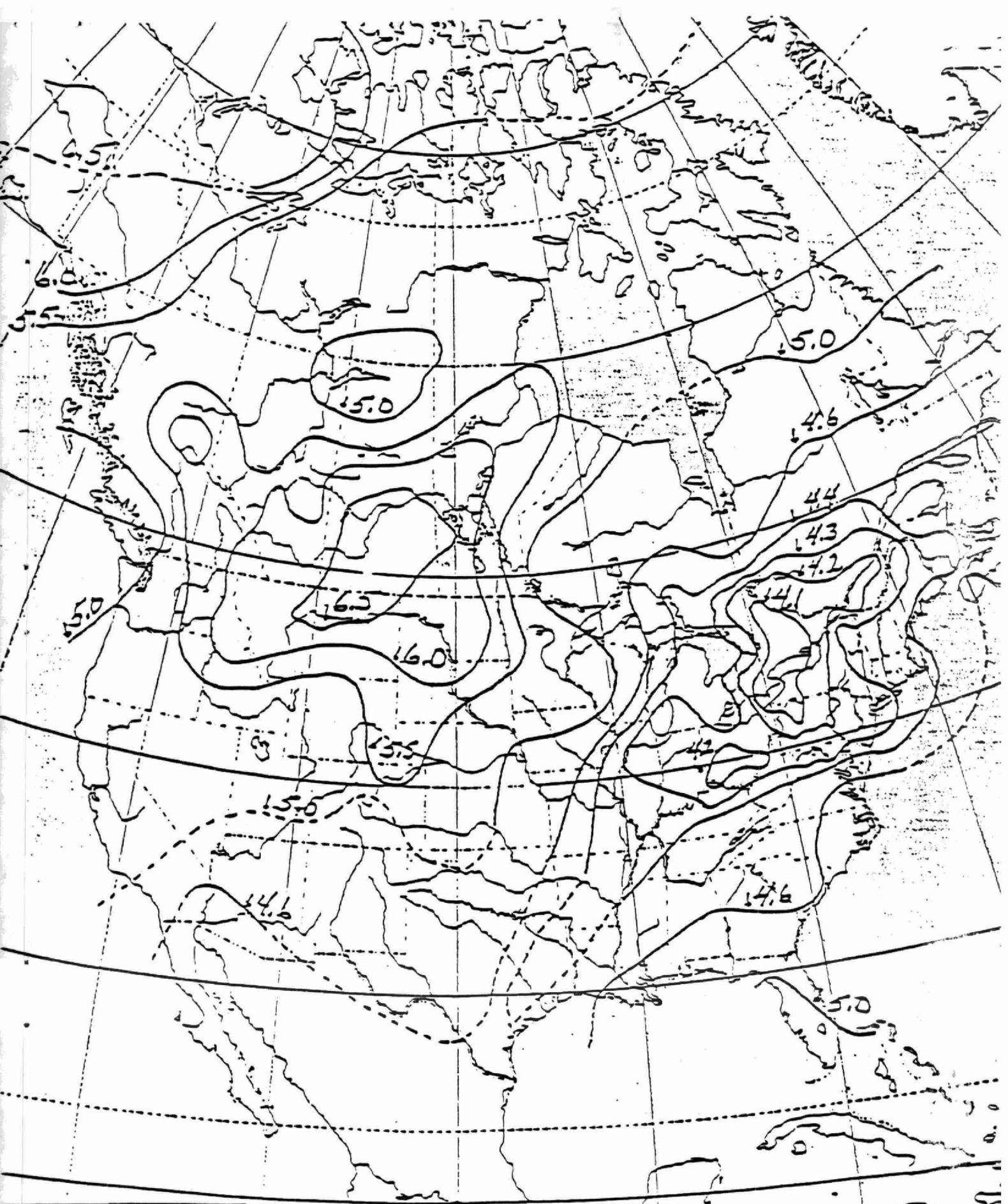


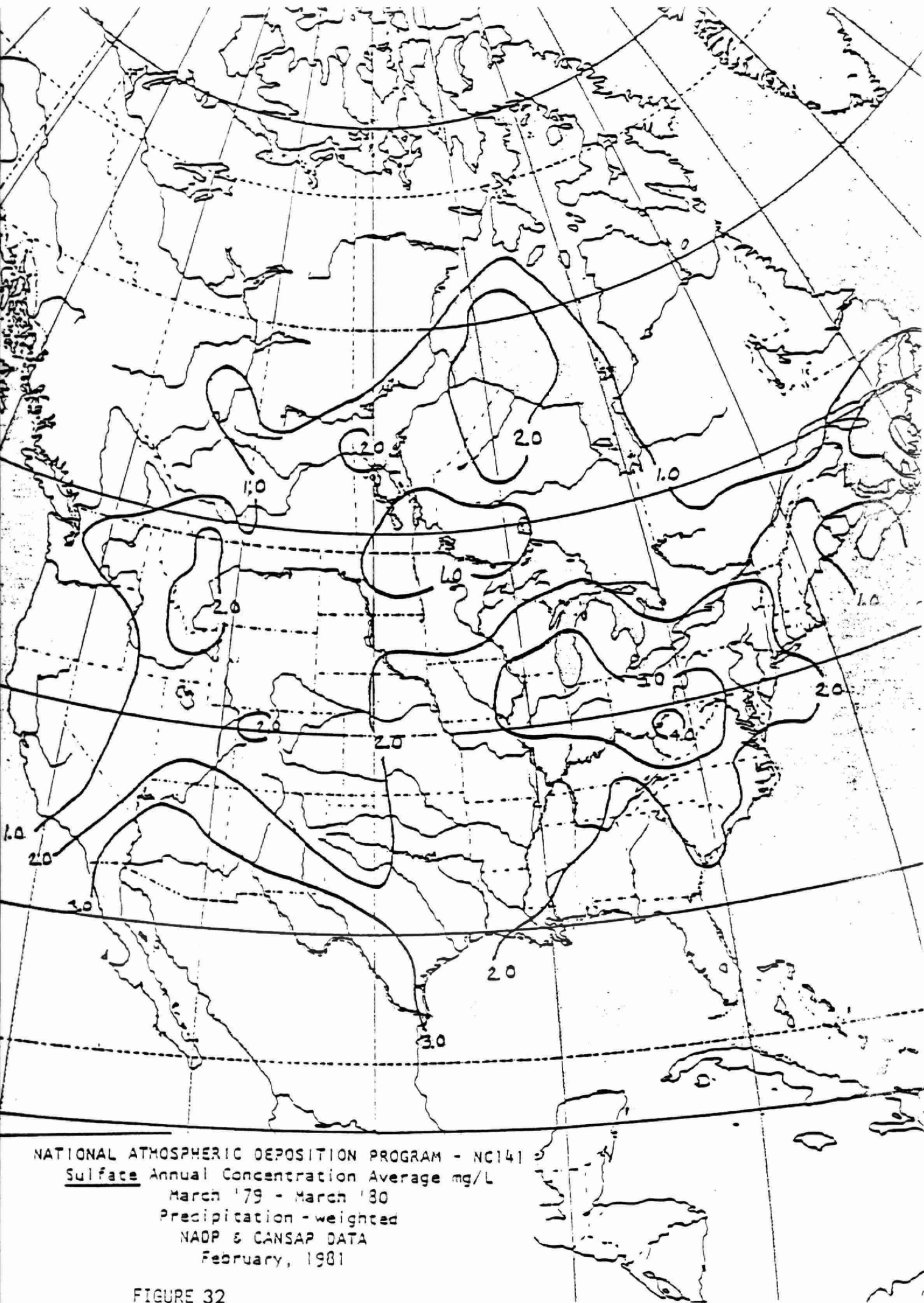
FIGURE 30 : MONTHLY CONCENTRATIONS OF PH, SO<sub>4</sub><sup>=</sup>, CA<sup>+</sup> AND NO<sub>3</sub><sup>-</sup> FOR THE NEMP PRECIPITATION NETWORK 1978-1979.



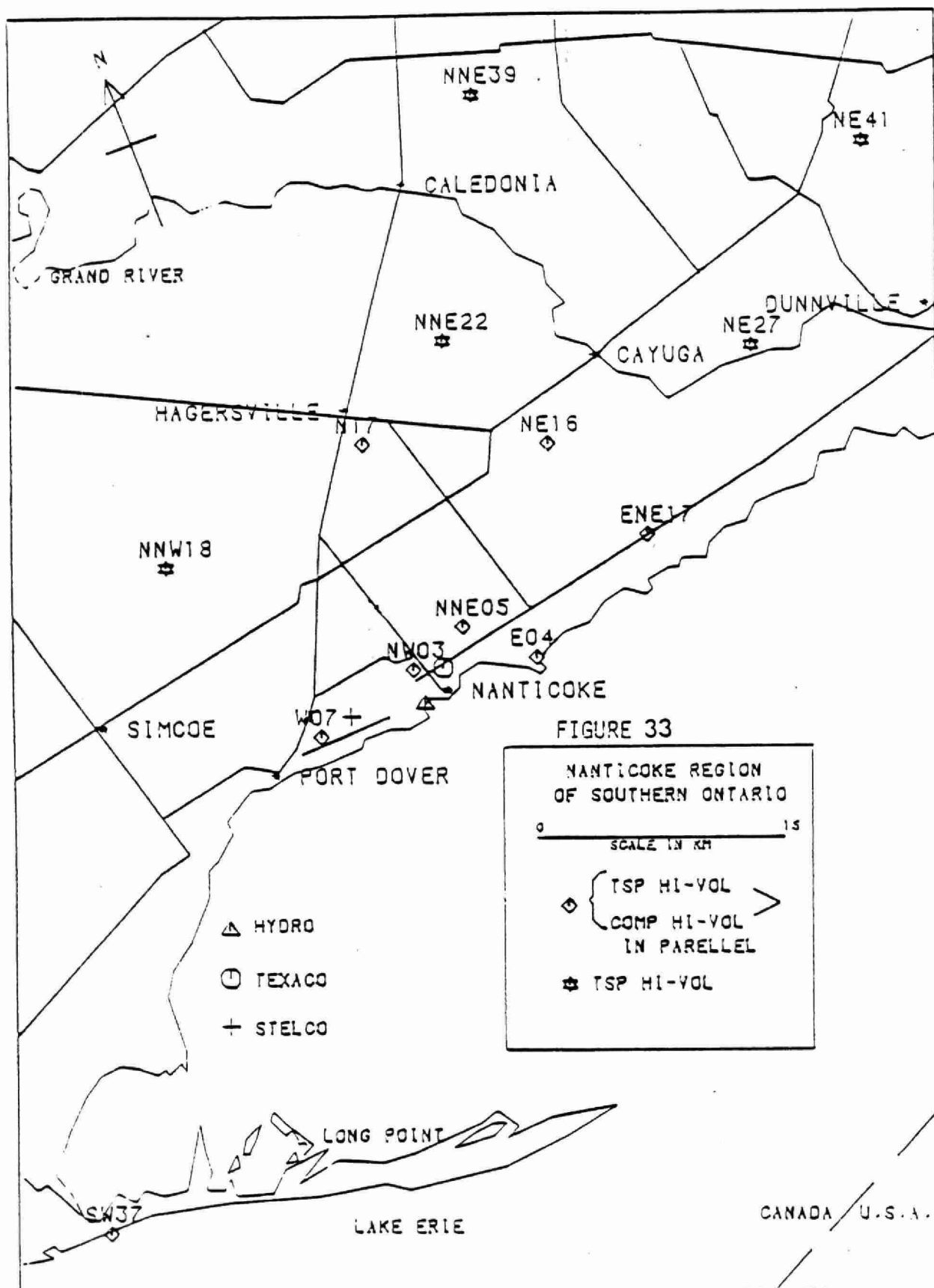
NATIONAL ATMOSPHERIC DEPOSITION PROGRAM  
pH ANNUAL AVERAGE - 1979  
Precipitation-Weighted  
NADP & CANSAP DATA  
November, 1980

FIGURE 31

0 200 400 600 800 1000  
Scale in Miles



# HI-VOL SAMPLING NETWORK



## APPENDIX I

### NEMP PRECIPITATION DATA COLLECTED DURING OCTOBER 1978 TO DECEMBER 1979

Data are presented on a monthly basis according to sampling station. All concentrations are expressed in ppm (water) except precipitation volume which is expressed in ml. Total acidity is expressed as  $\text{CaCO}_3$ . Sampling station SW40 was set up for intercomparison purposes. During the study period only four months of data was collected at SW40. Dashes represent missing or unavailable data. Included in the missing data category are those concentrations which were determined to be contaminated. It should also be noted that the  $\text{NO}_3$  and  $\text{NH}_4$  concentrations are expressed as N- $\text{NO}_3$  and N- $\text{NH}_4$  respectively.

PRECIPITATION ANALYSIS DATA FOR NEMP NETWORK:10/78

STATION	ACID	PH	SPCN	CL	F	N-NH4	N-NO3	NO2	SO4	TKN	TPH	CA	PRECIPITATION VOLUME
22902	3.16	4.25	-	1.93	-	1.000	1.00	1.250	8.30	-	.0195	1.30	1165.
22953	8.61	3.89	-	3.56	-	.550	.94	.650	5.40	-	.0045	.60	2712.
22954	-	4.31	-	1.12	.038	.807	1.09	.003	5.90	-	.0070	.59	1656.
22956	6.84	4.00	-	2.64	-	.440	.72	.525	4.20	-	.0030	.52	640.
22958	-	-	-	-	-	-	-	-	-	-	-	-	-
22959	-	-	-	-	-	-	-	-	-	-	-	-	-
22960	5.35	4.07	-	2.84	-	.340	.56	.414	3.30	-	.0020	.43	1725.
	CO	CU	FE	K	MO	MN	NA	NI	PB	P	SIO2	ZN	
22902	.0075	.012	.030	.70	.31	-	.90	.0080	.023	.0150	.080	.060	
22953	.0008	.006	.120	.14	.12	-	.20	.0150	.029	.0030	.057	.023	
22954	.0012	.006	.190	.47	.11	-	.20	.0040	.023	.0024	.064	.032	
22956	.0008	.004	.110	.12	.08	-	.20	.0120	.020	.0004	.054	.022	
22958	-	-	-	-	-	-	-	-	-	-	-	-	
22959	-	-	-	-	-	-	-	-	-	-	-	-	
22960	.0024	.004	.170	.10	.12	-	.20	.0230	.021	.0006	.039	.025	

PRECIPITATION ANALYSIS DATA FOR NEMP NETWORK:11/78

STATION	ACID	PH	SPCN	CL	F	N-NH4	N-NO3	NO2	SO4	TKN	TPH	CA	PRECIPITATION VOLUME
22902	3.63	4.90	-	2.51	-	.950	1.20	1.005	9.00	-	.0250	2.20	795.
22953	3.88	4.15	-	.59	-	.470	.61	.563	4.40	-	.0080	.30	1207.
22954	3.97	4.13	-	1.08	-	.520	.67	.614	4.80	-	.0030	.42	1610.
22956	6.55	3.97	-	2.33	-	.430	.75	.544	5.30	-	.0035	.35	1337.
22958	-	-	-	-	-	-	-	-	-	-	-	-	-
22959	-	-	-	-	-	-	-	-	-	-	-	-	-
22960	4.23	4.13	-	2.10	-	.480	.67	.570	4.50	-	.0020	.55	1101.
	CO	CU	FE	K	MO	MN	NA	NI	PB	P	SIO2	ZN	
22902	.0091	.004	.110	.15	.75	-	.30	.0210	.013	.0160	.130	.055	
22953	.0008	.004	.037	.08	.08	-	.20	.0550	.022	.0033	.054	.023	
22954	.0500	.004	.210	.08	.14	-	.20	.0360	.027	.0005	.053	.018	
22956	.0012	.007	.410	.13	.11	-	.30	.1000	.014	.0001	.040	.036	
22958	-	-	-	-	-	-	-	-	-	-	-	-	
22959	-	-	-	-	-	-	-	-	-	-	-	-	
22960	.0023	.005	.320	.08	.18	-	.20	.2700	.026	.0001	.050	.022	

ALL ELEMENTS ARE MEASURED IN PPM  
 PRECIPITATION VOLUMES ARE MEASURED IN ML  
 - SIGNIFIES DATA IS MISSING OR UNAVAILABLE

PRECIPITATION ANALYSIS DATA FOR NEMP NETWORK: 12/78

STATION	ACID	PH	SFCN	CL	F	N-NH4	N-NO3	NO2	SO4	TKN	TPH	CA	PRECIPITATION VOLUME
22902	24.21	-	-	.80	-	.301	-	.435	5.30	-	.0044	1.30	-
22953	4.00	4.10	-	.70	-	.111	.45	.172	3.20	-	.0050	.32	-
22954	6.11	4.10	-	1.60	-	.234	.34	.278	3.10	-	.0067	.20	-
22956	4.21	4.00	-	1.00	-	.142	.67	.202	3.30	-	.0057	.20	-
22958	-	-	-	-	-	-	-	-	-	-	-	-	-
22959	-	-	-	-	-	-	-	-	-	-	-	-	-
22960	41.58	-	-	1.40	-	.195	-	.333	2.70	-	.0100	.37	-
	CD	CU	FE	K	MG	MN	NA	NI	PB	P	S102	ZN	
22902	.0024	.004	.025	.41	.32	-	.37	.0070	.017	.0012	-	.036	-
22953	.0030	.006	.050	.24	.09	-	.32	.0100	.009	.0028	.037	.023	-
22954	.0050	.003	.080	.12	.05	-	.30	.0040	.012	.0019	.021	.013	-
22956	.0012	.009	.100	.06	.05	-	.29	.0035	.013	.0031	.023	.014	-
22958	-	-	-	-	-	-	-	-	-	-	-	-	-
22959	-	-	-	-	-	-	-	-	-	-	-	-	-
22960	.0028	.005	.200	.19	.07	-	.21	.0110	.021	.0012	.030	.027	-

PRECIPITATION ANALYSIS DATA FOR NEMP NETWORK: 1/79

STATION	ACID	PH	SFCN	CL	F	N-NH4	N-NO3	NO2	SO4	TKN	TPH	CA	PRECIPITATION VOLUME
22902	-	-	289.00	1.66	.020	.188	.52	.001	-	-	-	.65	1385.
22953	-	3.80	64.00	1.13	.070	.261	.72	.001	6.10	-	-	.66	1365.
22954	-	3.90	42.00	.79	.030	.313	.54	.003	4.50	-	-	.25	1405.
22956	-	-	266.00	.54	.020	.145	.45	.001	-	-	-	.20	2035.
22958	-	-	-	-	-	-	-	-	-	-	-	-	-
22959	-	-	-	-	-	-	-	-	-	-	-	-	-
22960	-	3.90	268.00	1.33	.020	.174	.39	.005	3.70	-	-	.19	1180.
	CD	CU	FE	K	MG	MN	NA	NI	PB	P	S102	ZN	
22902	.0016	.006	.200	.10	.13	.006	.36	.0020	.008	-	-	.150	-
22953	.0021	.013	.290	.05	.06	.004	.22	.0020	.013	-	-	.090	-
22954	.0010	.004	.070	.10	.01	.003	.20	.0010	.005	-	-	2.800	-
22956	.0013	.009	.026	.06	.04	.002	.22	.0010	.006	-	-	.030	-
22958	-	-	-	-	-	-	-	-	-	-	-	-	-
22959	-	-	-	-	-	-	-	-	-	-	-	-	-
22960	.0019	.007	.200	.03	.02	.002	.19	.0020	.007	-	-	2.200	-

ALL ELEMENTS ARE MEASURED IN PPM  
 PRECIPITATION VOLUMES ARE MEASURED IN ML  
 - SIGNIFIES DATA IMPOUR OR UNAVAILABLE

## PRECIPITATION ANALYSIS DATA FOR NEMP NETWORK: 2/79

STATION	ACID	PH	SFCN	CL	F	N-NH4	N-HO3	NO2	SO4	TKN	TPH	CA	PRECIPITATION VOLUME
22902	-	-	-	-	-	-	-	-	-	-	-	-	152.
22953	-	-	-	-	.050	.220	1.14	.001	7.10	-	-	1.46	456.
22954	-	-	-	-	.040	.255	.89	.001	5.50	-	-	.56	299.
22956	-	-	-	-	.040	.224	1.14	.001	6.30	-	-	1.07	192.
22958	-	-	-	-	.090	1.540	1.81	.001	1.20	-	-	2.72	175.
22959	-	-	-	-	-	-	-	-	-	-	-	-	-
22960	-	-	-	-	-	-	-	-	10.10	-	-	-	156.

	CD	CU	FE	K	HG	MN	NA	NI	FB	P	SI02	ZN
22902	.0003	.004	.200	.59	-	-	2.50	.0030	.002	-	-	.190
22953	.0003	.006	.150	.08	.27	.011	.42	.0070	.011	-	-	.210
22954	.0002	.007	.120	.07	.07	-	.31	.0030	.008	-	-	.110
22956	.0010	.010	.150	.12	.22	.008	.58	.0070	.011	-	-	.130
22958	.0017	.007	.120	.22	.86	.021	1.10	.0070	.010	-	-	.130
22959	-	-	-	-	-	-	-	-	-	-	-	-
22960	.0016	.008	.200	.23	-	-	1.45	.0050	.015	-	-	.100

## PRECIPITATION ANALYSIS DATA FOR NEMP NETWORK: 3/79

STATION	ACID	PH	SFCN	CL	F	N-NH4	N-HO3	NO2	SO4	TKN	TPH	CA	PRECIPITATION VOLUME
22902	-	-	263.00	-	.030	.591	1.08	.001	6.30	-	-	.88	1300.
22953	-	-	100.00	-	.030	.465	1.03	.001	5.50	-	-	.60	1300.
22954	-	3.90	58.00	1.04	.020	.394	.85	.001	4.40	-	-	.40	1025.
22956	-	3.80	76.00	1.36	.030	.530	1.12	.001	6.00	-	-	.65	1315.
22958	-	-	-	-	-	-	-	-	-	-	-	-	-
22959	-	-	-	-	.090	2.390	2.24	.001	15.50	-	-	3.12	1517.
22960	-	-	279.00	-	.020	.413	.74	.001	4.50	-	-	.41	1270.

	CD	CU	FE	K	HG	MN	NA	NI	FB	P	SI02	ZN
22902	.0006	.020	.110	.08	.20	.010	.31	.0030	.008	-	-	.080
22953	.0003	.015	.080	.07	.08	.007	.20	.0020	.008	-	-	.200
22954	.0002	.013	.050	.05	.06	.005	.23	.0020	.006	-	-	.220
22956	.0001	.007	.060	.09	.11	.008	.25	.0030	.007	-	-	.150
22958	-	-	-	-	-	-	-	-	-	-	-	-
22959	.0010	.031	.310	.35	.92	.016	.81	.0030	.010	-	-	2.000
22960	.0000	.011	.100	.05	.07	.005	.19	.0030	.005	-	-	.500

ALL ELEMENTS ARE MEASURED IN PPM  
 PRECIPITATION VOLUMES ARE MEASURED IN ML  
 - INDICATES DATA UNAVAILABLE OR UNOBTAINABLE

PRECIPITATION ANALYSIS DATA FOR NEMP NETWORK: 4/79

STATION	ACID	PH	SPCH	CL	F	N-NH4	N-HO3	NO2	SO4	TKN	TPH	CA	PRECIPITATION VOLUME
22902	-	-	192.00	-	.050	.894	1.34	.001	8.60	-	-	1.78	902.
22953	-	-	89.00	-	.020	.323	.74	.001	4.40	-	-	.43	2664.
22954	-	3.90	60.00	1.34	.020	.356	.74	.003	4.90	-	-	.60	724.
22956	-	3.90	57.00	.71	.020	.306	.80	.002	5.10	-	-	.47	2534.
22958	-	4.10	-	1.06	.030	1.070	.99	.002	.70	-	-	1.03	2266.
22959	-	-	-	-	-	-	-	-	-	-	-	-	-
22960	-	4.00	53.00	1.92	.020	.326	.65	.001	4.40	-	-	.91	1445.
	CD	CU	FE	K	HG	MN	NA	NI	PB	P	SI02	ZN	
22902	.0021	.040	.350	.14	.45	.021	.42	.0060	.015	-	-	.130	
22953	.0010	.060	.080	.05	.08	.005	.15	.0010	.007	-	-	.070	
22954	.0003	.055	.020	.05	.12	.010	.12	.0010	.006	-	-	.040	
22956	.0008	.030	.070	.09	.13	.006	.20	.0020	.008	-	-	.210	
22958	.0063	.033	.200	.12	.33	.010	.28	.0020	.007	-	-	.180	
22959	-	-	-	-	-	-	-	-	-	-	-	-	
22960	.0006	.027	.015	.05	.25	.005	.13	.0010	.006	-	-	.090	

PRECIPITATION ANALYSIS DATA FOR NEMP NETWORK: 5/79

STATION	ACID	PH	SPCH	CL	F	N-NH4	N-HO3	NO2	SO4	TKN	TPH	CA	PRECIPITATION VOLUME
22902	-	3.90	69.00	1.40	.040	.919	1.00	.002	8.40	-	-	1.08	1236.
22953	-	3.80	71.00	.80	.030	1.100	1.06	.001	8.70	-	-	.80	1300.
22954	-	3.90	86.00	1.16	.030	.888	.82	.001	6.30	-	-	.04	1623.
22956	-	3.80	80.00	2.05	.030	.788	1.08	.001	6.60	-	-	.67	1500.
22958	-	-	-	-	-	-	-	-	-	-	-	-	-
22959	-	3.80	-	.58	.050	-	1.52	.001	10.30	-	-	1.05	1194.
22960	-	4.00	57.00	1.06	.030	.910	.85	.020	6.20	-	-	.60	1212.
	CD	CU	FE	K	HG	MN	NA	NI	PB	P	SI02	ZN	
22902	.0007	.016	.024	.00	.26	.012	.13	.0010	.007	-	-	.060	
22953	.0006	.006	.022	.14	.16	.011	.25	.0020	.008	-	-	.290	
22954	.0005	.046	.019	.10	.13	.010	.15	.0020	.007	-	-	.100	
22956	.0067	.036	.023	.12	.16	.010	.22	.0020	.007	-	-	.590	
22958	-	-	-	-	-	-	-	-	-	-	-	-	
22959	.0010	.008	.010	.12	.28	.012	.20	.0050	.011	-	-	.130	
22960	.0010	.025	.014	.26	.14	.007	.22	.0010	.007	-	-	.060	

ALL ELEMENTS ARE MEASURED IN PPM  
 PRECIPITATION VOLUMES ARE MEASURED IN ML  
 DASHES DATA INVALID OR UNAVAILABLE

PRECIPITATION ANALYSIS DATA FOR NEMP NETWORK: 6/79

STATION	ACID	PH	SPCN	CL	F	N-NH4	N-NO3	NO2	SO4	TKN	TPH	CA	PRECIPITATION VOLUME
22902	-	3.80	83.00	.52	.030	.730	1.03	.001	9.50	-	-	.93	1117.
22953	-	-	133.00	-	.020	.454	.88	.002	7.20	-	-	.72	2021.
22954	-	3.80	81.00	1.24	.030	1.140	1.06	.005	9.60	-	-	.85	1441.
22956	-	3.80	70.00	.57	.030	.600	.87	.004	7.70	-	-	.70	1702.
22958	-	-	-	1.90	.040	1.490	1.54	.001	-	-	-	1.82	1051.
22959	-	-	-	-	-	-	-	-	-	-	-	-	-
22960	-	-	233.00	-	.020	.512	.75	.001	6.60	-	-	.75	1261.
	CD	CU	FE	K	HG	MN	NA	NI	PB	P	SIO2	ZN	
22902	.0003	.012	.160	.12	.22	.017	.20	.0030	.008	-	-	.100	
22953	.0002	.018	.350	.08	.11	.012	.13	.0150	.008	-	-	.230	
22954	.0016	.018	.140	.26	.18	.016	.40	.0120	.009	-	-	2.800	
22956	.0004	.014	.090	.11	.18	.010	.19	.0020	.007	-	-	.590	
22958	.0004	.015	.180	.15	.50	.020	.20	.0050	.012	-	-	.140	
22959	-	-	-	-	-	-	-	-	-	-	-	-	
22960	.0011	.017	.120	.11	.18	.012	.14	.0160	.008	-	-	.030	

PRECIPITATION ANALYSIS DATA FOR NEMP NETWORK: 7/79

STATION	ACID	PH	SPCN	CL	F	N-NH4	N-NO3	NO2	SO4	TKN	TPH	CA	PRECIPITATION VOLUME
22902	-	4.10	53.00	1.79	.030	1.060	.82	.001	9.40	-	-	1.62	618.
22953	-	4.00	53.00	1.10	.020	.294	.40	.002	5.40	-	-	.76	1218.
22954	-	-	92.00	-	.020	.551	.87	.001	7.50	-	-	.78	940.
22956	-	-	-	-	-	-	-	-	-	-	-	-	99.
22958	-	-	-	-	-	-	-	-	-	-	-	-	-
22959	-	4.10	-	.65	.020	.647	.57	.002	8.00	-	-	1.08	1038.
22960	-	3.80	77.00	1.73	.020	.821	.81	.001	8.70	-	-	.91	981.
	CD	CU	FE	K	HG	MN	NA	NI	PB	P	SIO2	ZN	
22902	.0010	.084	.250	.29	.37	.011	.36	.0040	.010	-	-	.300	
22953	.0004	.010	.040	.10	.21	.006	.15	.0020	.005	-	-	.200	
22954	.0009	.012	.170	.12	.25	.008	.20	.0030	.011	-	-	.110	
22956	.0003	.020	.900	-	-	-	-	.0150	.042	-	-	.500	
22958	-	-	-	-	-	-	-	-	-	-	-	-	
22959	.0005	.008	.100	.30	.37	.007	.12	.0030	.005	-	-	.200	
22960	.0009	.026	.150	.11	.37	.011	.11	.0060	.007	-	-	.120	

ALL ELEMENTS ARE MEASURED IN TPN  
 PRECIPITATION VOLUMES ARE MEASURED IN ML  
 - SIGNIFIES DATA DELETED OR UNAVAILABLE

PRECIPITATION ANALYSIS DATA FOR NEMP NETWORK: 8/79

STATION	ACID	PH	SPCN	CL	F	N-NH4	N-NO3	NO2	SO4	TKN	TFH	CA	PRECIPITATION VOLUME
22902	5.60	4.00	57.50	.96	.027	.261	.42	.001	5.20	.597	.0283	.30	2137.
22953	4.70	4.00	57.80	1.21	.028	.486	.54	.002	6.10	1.010	.0870	.62	3925.
22954	5.00	4.00	57.50	.76	.028	.412	.35	.002	6.00	.567	.0045	.59	4120.
22955	4.00	3.90	62.40	.62	.028	.303	.58	.001	6.00	.414	.0049	.25	2923.
22958	6.50	3.90	75.10	.54	.028	.250	.78	.003	-	1.250	.0170	.49	1920.
22959	-	-	-	-	-	-	-	-	-	-	-	-	-
22960	2.50	4.30	40.10	.62	.023	.979	.45	.001	5.40	1.030	.1100	.12	3339.
	CD	CU	FE	K	HG	MN	NA	NI	PB	P	SI02	ZH	
22902	.0017	.000	.022	.10	.11	.006	.10	.0035	.008	-	-	.025	
22953	.0008	.004	.025	.11	.15	.011	.17	.0020	.011	-	-	.030	
22954	.0018	.006	.026	.12	.14	.011	.11	.0020	.013	-	-	.020	
22955	.0007	.003	.021	.05	.13	.008	.06	.0015	.011	-	-	.014	
22958	.0008	.003	.043	.09	.26	.008	.11	.0025	.014	-	-	.019	
22959	-	-	-	-	-	-	-	-	-	-	-	-	
22960	.0020	.002	.019	.08	.15	.007	.16	.0050	.008	-	-	.017	

PRECIPITATION ANALYSIS DATA FOR NEMP NETWORK: 9/79

STATION	ACID	PH	SPCN	CL	F	N-NH4	N-NO3	NO2	SO4	TKN	TFH	CA	PRECIPITATION VOLUME
22902	1.60	4.40	22.40	.40	.022	.114	.29	.004	2.90	.294	.0051	.42	1869.
22953	1.10	4.50	22.10	1.40	.015	.462	.27	.004	3.90	.961	.0760	.45	1773.
22954	5.00	4.00	49.50	-	.013	.177	.19	.001	2.40	.359	.0073	.35	1773.
22955	1.30	4.50	25.00	.60	.015	.160	.23	.004	3.40	.347	.0183	.46	1999.
22958	-	-	-	-	-	-	-	-	-	-	-	-	-
22959	1.00	4.40	29.50	1.10	.014	.501	.22	.004	3.60	.705	.0388	.35	3254.
22960	1.70	4.40	25.40	1.00	.014	.117	.18	.001	2.40	.280	.0085	.35	960.
	CD	CU	FE	K	HG	MN	NA	NI	PB	P	SI02	ZH	
22902	.0004	.003	.020	.03	.08	.009	.05	.0040	.006	-	-	.016	
22953	.0004	.003	.020	.09	.12	.007	.19	.0020	.006	-	-	.015	
22954	.0005	.004	.031	.09	.14	.008	.09	.0025	.006	-	-	.020	
22955	.0001	.001	.017	.03	.18	.007	.05	.0015	.005	-	-	.008	
22958	-	-	-	-	-	-	-	-	-	-	-	-	
22959	.0015	.001	.008	.01	.19	.006	.09	.0015	.005	-	-	.006	
22960	.0005	.004	.021	.03	.09	.007	.05	.0070	.007	-	-	.016	

ALL ELEMENTS ARE MEASURED IN PPM  
 PRECIPITATION VOLUMES ARE MEASURED IN ML  
 \* SOME VALUES MAY BE UNAVAILABLE

PRECIPITATION ANALYSIS DATA FOR NEMP NETWORK:10/79

STATION	ACID	PH	SPCH	CL	F	N-NH4	N-HO3	NO2	SO4	TKN	TPH	CA	PRECIPITATION VOLUME
22902	6.90	3.90	73.60	.64	.042	.797	1.32	.003	5.60	.980	.0112	1.60	1396.
22953	7.00	3.90	87.10	.87	.052	1.050	1.58	.004	8.70	1.570	.0193	1.30	1316.
22954	5.90	4.00	65.80	-	-	-	-	-	-	.740	.0205	.62	2227.
22956	8.00	3.90	83.00	1.49	.040	.593	1.24	.005	4.80	.812	.0174	.71	2795.
22958	5.70	4.00	79.50	1.34	.050	1.870	1.52	.003	9.30	2.490	.1068	1.50	1929.
22959	-	-	-	-	-	-	-	-	-	-	-	-	-
22960	7.70	3.90	79.50	2.44	.033	.544	.99	.003	4.90	.695	.0162	.50	1603.
STATION	CD	CU	FE	K	HG	MN	NA	NI	FB	P	S102	ZN	
22902	.0004	.002	.030	.07	.20	.013	.06	.0015	.019	-	-	.017	
22953	.0006	.003	.042	.10	.22	.016	.10	.0020	.025	-	-	.028	
22954	.0005	.002	.015	.10	.15	.011	.10	.0015	.019	-	-	.018	
22956	.0003	.002	.028	.09	.17	.013	.08	.0010	.018	-	-	.015	
22958	.0006	.003	.035	.20	.30	.016	.13	.0020	.019	-	-	.025	
22959	-	-	-	-	-	-	-	-	-	-	-	-	
22960	.0012	.002	.020	.07	.13	.011	.08	.0020	.015	-	-	.019	

PRECIPITATION ANALYSIS DATA FOR NEMP NETWORK:11/79

STATION	ACID	PH	SPCH	CL	F	N-NH4	N-HO3	NO2	SO4	TKN	TPH	CA	PRECIPITATION VOLUME
22902	3.16	4.10	41.90	.44	.027	.416	.74	.003	3.50	.503	.0123	.04	2010.
22953	-	-	-	-	-	-	-	-	-	-	-	-	-
22954	3.64	4.00	41.40	.62	.026	.400	.67	.005	3.31	.472	.0133	.05	2893.
22956	4.89	4.00	53.10	.53	.025	.453	.96	.003	4.09	.555	.0123	.40	2227.
22958	.00	5.50	76.40	1.13	.076	2.620	2.00	.001	-	4.640	.2370	3.30	1695.
22959	-	-	-	-	-	-	-	-	-	-	-	-	-
22960	3.12	4.10	37.90	.53	.022	.422	.72	.026	2.99	.554	.0091	.40	1430.
STATION	CD	CU	FE	K	HG	MN	NA	NI	FB	P	S102	ZN	
22902	.0097	.002	.023	.05	.08	.005	.15	.0006	.012	-	-	.015	
22953	-	-	-	-	-	-	-	-	-	-	-	-	
22954	.0011	.002	.023	.06	.05	.005	.15	.0012	.011	-	-	.011	
22956	.0097	.004	.019	.11	.10	.005	.16	.0012	.019	-	-	.024	
22958	.0012	.005	.015	1.00	1.12	.024	.48	.0050	.010	-	-	.047	
22959	-	-	-	-	-	-	-	-	-	-	-	-	
22960	.0021	.007	.028	.10	.08	.005	.19	.0034	.013	-	-	.029	

ALL ELEMENTS ARE MEASURED IN PPM  
 PRECIPITATION VOLUMES ARE MEASURED IN ML  
 - = SIGNIFIED DATA THOUGH BE UNAVAILABLE

PRECIPITATION ANALYSIS DATA FOR HEMP NETWORK:12/79

STATION	ACID	PH	SECH	CL	F	N-NH4	N-NO3	NO2	SO4	TKN	TPH	CA	PRECIPITATION VOLUME
22902	2.69	4.20	32.20	.21	.017	.256	.45	.003	3.01	.343	.0069	.30	-
22953	3.35	4.10	30.50	.25	.019	.353	.64	.004	3.32	.453	.0079	.30	-
22954	2.83	4.20	31.00	.19	.016	.225	.44	.004	2.59	.327	.0070	.20	-
22956	2.98	4.20	35.50	.36	.019	.236	.61	.004	2.99	.331	.0092	.40	-
22958	2.44	4.20	34.80	.27	.022	.661	.65	.004	3.58	.778	.0075	.40	-
22959	-	-	-	-	-	-	-	-	-	-	-	-	-
22960	3.14	4.20	36.00	.28	.020	.301	.51	.004	2.06	.404	.0058	.20	-
	CO	CU	FE	K	MG	MN	NA	NI	PB	P	SI02	ZN	
22902	.0006	.001	.012	.05	.07	.003	.05	.0005	.006	-	-	.007	-
22953	.0005	.001	.016	.05	.05	.004	.12	.0010	.009	-	-	.009	-
22954	.0007	.002	.014	.05	.03	.003	.09	.0005	.010	-	-	.010	-
22956	.0009	.003	.016	.04	.10	.003	.10	.0010	.014	-	-	.014	-
22958	.0008	.003	.014	.03	.10	.004	.10	.0005	.014	-	-	.012	-
22959	-	-	-	-	-	-	-	-	-	-	-	-	-
22960	.0005	.001	.011	.05	.03	.003	.08	.0010	.009	-	-	.008	-

ALL ELEMENTS ARE MEASURED IN PPM  
 PRECIPITATION VOLUMES ARE MEASURED IN ML  
 - SIGNIFIES DATA INVALID OR UNAVAILABLE

## APPENDIX 2

### INTERCOMPARISON OF NEMP NETWORK RESULTS WITH AES AND ONTARIO HYDRO STATION IN THE NANTICOKE REGION

In addition to MOE, within the Nanticoke area, precipitation sampling is also conducted by Ontario Hydro and the Atmospheric Environment Service (AES). The AES has a monthly CANSAP sampling station at Simcoe and an event APN sampler at Long Point, and Ontario Hydro collects data from an event sampler at E05. It was felt that the results from a paired-t test using data from the closest two stations in the NEMP network versus data from the other sampling agencies would assess the validity of the NEMP precipitation data. W07 and NNW18 were the NEMP stations chosen for the analysis.  $\text{H}^+$ ,  $\text{SO}_4^-$ ,  $\text{NO}_3^-$  and  $\text{Ca}^+$  were the parameters included in the paired-t tests. Mean sample difference, standard deviation of the mean difference and the calculated t statistic for each pair of stations, appear in Table 11. The results indicate that for the most part, there is no statistical difference at the 95% confidence level between precipitation samples collected by the NEMP, CANSAP, APN and Ontario Hydro samplers in the Nanticoke area. Figure 34 shows the levels of  $\text{SO}_4^-$ ,  $\text{NO}_3^-$ ,  $\text{Ca}^+$ ,  $\text{NH}_4^+$  and  $\text{H}^+$  for the NEMP (W07), NEMP (NNW18) and CANSAP (Simcoe) stations.

A similar trend is apparent in the data from all three networks.

TABLE 11

## PAIRED T-TEST RESULTS FOR H4 PARAMETER

STATION	MEAN DIFFERENCE	STANDARD DEVIATION	t STATISTIC	df	HYPOTHESIS*
W07 (NEMP)					
SIMCOE (CANSAP)	-.040	.077	-1.813	11	T
W07 (NEMP)					
PEACOCK PT (HYDRO)	.075	.0915	2.511	8	F
W07 (NEMP)					
LONG PT (APN)	.043	.056	2.291	8	T
NNW18 (NEMP)					
SIMCOE (CANSAP)	.020	.047	1.600	10	T
NNW18 (NEMP)					
PEACOCK PT (HYDRO)	.053	.064	2.467	8	F
NNW18 (NEMP)					
LONG (APN)	.031	.043	2.041	7	T

\* HYPOTHESIS -- THERE IS NO STATISTICAL DIFFERENCE BETWEEN PRECIPITATION  
SAMPLES AT THE 95% CONFIDENCE LEVEL.

TABLE 11 con't

## PAIRED T-TEST RESULTS FOR Ca PARAMETER

STATION	MEAN DIFFERENCE	STANDARD DEVIATION	t STATISTIC	df	HYPOTHESES*
W07 (NEMP)					
SIMCOE (CANSAP)	-.210	.4903	-1.545	12	T
W07 (NEMP)					
PEACOCK PT (HYDRO)	-.511	1.05	-1.669	10	T
W07 (NEMP)					
LONG PT (APN)	.278	.421	2.191	10	T
HNW18 (NEMP)					
SIMCOE (CANSAP)	-.425	0.363	-4.218	12	F
HNW18 (NEMP)					
PEACOCK PT (HYDRO)	-.691	1.174	-1.951	10	T
HNW18 (NEMP)					
LONG (APN)	.045	.428	.332	9	T

\* HYPOTHESIS -- THERE IS NO STATISTICAL DIFFERENCE BETWEEN PRECIPITATION  
SAMPLES AT THE 95% CONFIDENCE LEVEL.

TABLE 11 con't

## PAIRED T-TEST RESULTS FOR SO4 PARAMETER

STATION	MEAN DIFFERENCE	STANDARD DEVIATION	t STATISTIC	df	HYPOTHESES†
W07 (NEMP) SINCOE (CANSAP)	1.02	1.99	1.841	12	T
W07 (NEMP) PEACOCK PT (HYDRO)	-1.80	4.56	-1.310	10	T
W07 (NEMP) LONG PT (APN)	2.39	1.18	5.696	10	F
NRW18 (NEMP) SINCOE (CANSAP)	1.48	1.17	4.383	11	F
NRW18 (NEMP) PEACOCK PT (HYDRO)	-1.77	4.58	-1.285	10	T
NRW18 (NEMP) LONG (APN)	1.21	1.72	2.216	9	T

† HYPOTHESIS --- THERE IS NO STATISTICAL DIFFERENCE BETWEEN PRECIPITATION  
SAMPLES AT THE 95% CONFIDENCE LEVEL.

TABLE 11 con't

PAIRED T-TEST RESULTS FOR NO<sub>3</sub><sup>-</sup> PARAMETER

STATION	MEAN DIFFERENCE	STANDARD DEVIATION	t STATISTIC	df	HYPOTHESIS
NO7 (NEMP) -SAND DE (CANSAP)	0.609	1.306	1.746	13	T
NO7 (NEMP) PEEBUCK PT (HYDRO)	-1.209	2.476	-1.619	10	T
NO7 (NEMP) LUND PT (APN)	0.335	1.046	1.013	9	T
NOVUS (NEMP) -SAND DE (CANSAP)	0.919	0.919	3.607	12	F
NOVUS (NEMP) PEEBUCK PT (HYDRO)	-1.288	2.666	-1.602	0	T
NOVUS (NEMP) LUND PT (APN)	-0.112	0.908	-0.390	9	T

T HYPOTHESIS -- THERE IS NO STATISTICAL DIFFERENCE BETWEEN PRECIPITATION  
SAMPLES AT THE 95% CONFIDENCE LEVEL

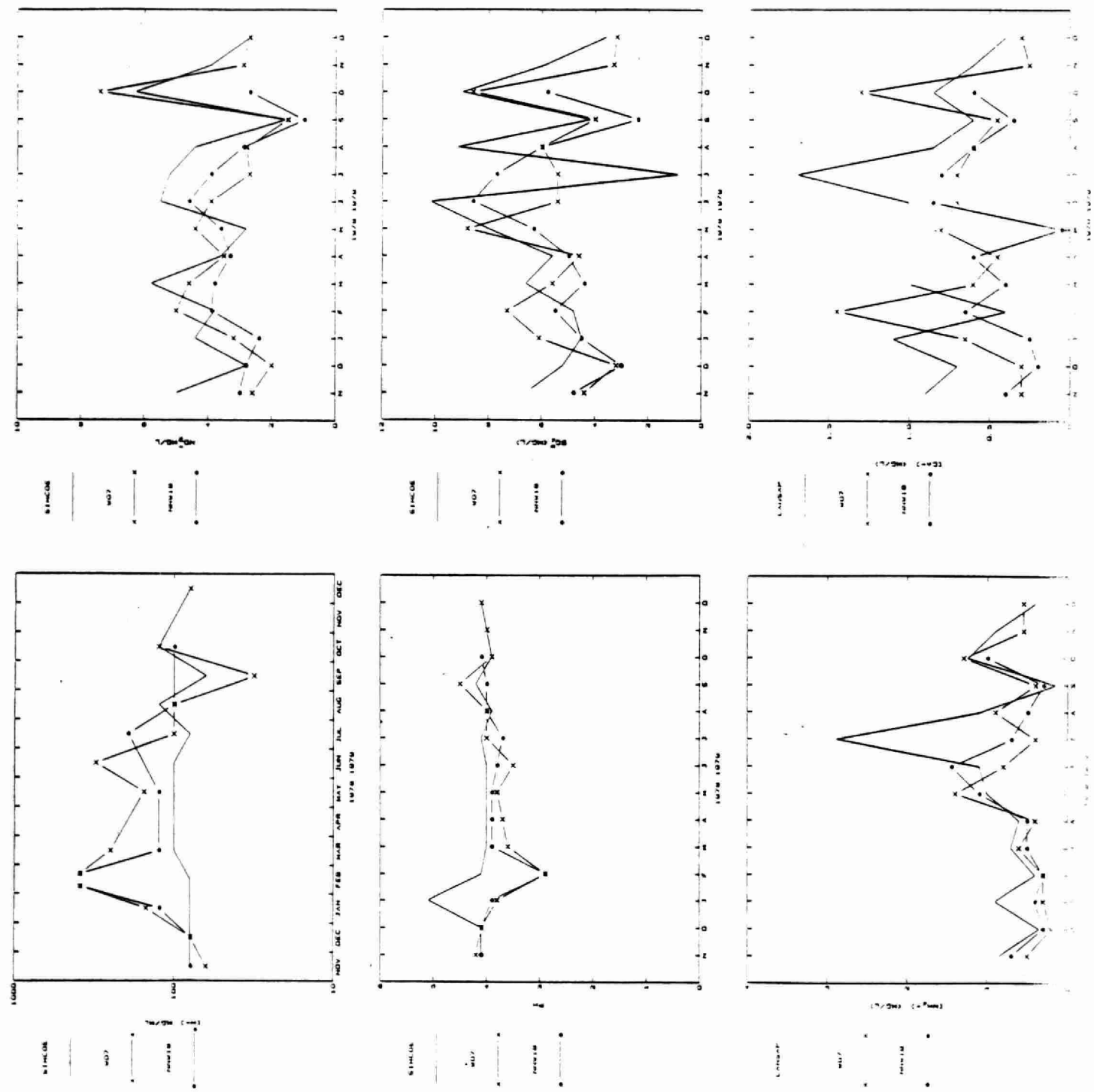


Figure 34 COMPARISON OF NEMP VERSUS CANSAP MONTHLY

